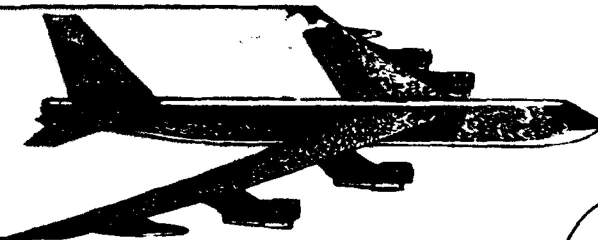

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Operational Test and Evaluation of Electronic Combat Systems

FREDERICK L. WRIGHT
Major, USAF

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Operational Test and Evaluation of Electronic Combat Systems

by

FREDERICK L. WRIGHT
Major, USAF

ARI Command-Sponsored Research Fellow
Air Force Operational Test and Evaluation Center

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This publication has been reviewed by security and policy review authorities and is cleared for public release.

To my parents,

Fred and Gail Wright

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Foreword

The Air Force must improve its test and evaluation process to correct the existing problems and failures in acquiring electronic combat (EC) systems. We must become a great deal better at implementing a test process which provides evidence that the system performs as expected in an operational environment before proceeding to full-scale production. Operational test and evaluation (OT&E) is the principal means for assessing the system's operational effectiveness and suitability and determining the extent that the EC system satisfies operational requirements.

Results from OT&E are of particular value to decision makers because they are derived from test agencies that are independent of the developing and using commands. They provide information that decision makers can use when determining the merits of continuing the acquisition program and reducing program risks. And yet, when operational testing does not provide sufficient information or the type of information decision makers are looking for at program decision points, the acquisition program becomes stalled until further testing is completed, adding time and expense to the program.

Maj Frederick L. Wright has taken a significant step toward addressing the concern that the Air Force does not have a structured EC test process. He has designed a process that can standardize the test procedures for the evaluation of EC systems and supply the type of information decision makers are expecting at the conclusion of testing. His study offers many insights into the challenge of testing EC systems and provides the reader with a description of the type of OT&E to be conducted in each phase of the acquisition process. I am convinced that anyone associated with OT&E of EC systems or any other weapon system would benefit greatly from a close examination of this study.

Donald M. Douglas

DONALD M. DOUGLAS, Col, USAF
Director of System Analysis
Headquarters Air Force Operational
Test and Evaluation Center

About the Author

Maj Frederick L. Wright

Maj Frederick L. ("Larry") Wright completed this study while assigned to the Airpower Research Institute, Air University Center for Aerospace Doctrine, Research, and Education (AUCADRE), Maxwell Air Force Base (AFB), Alabama. Major Wright began his career as a B-52 electronic warfare officer assigned to the 2d Bombardment Squadron, March AFB, California. In 1983, Major Wright was sent to the 453d Flight Training Squadron, Mather AFB, California, as an academic instructor in basic electronics, radar operations, and electronic countermeasures. Later, as an electronic warfare curriculum manager, he developed and wrote the course material for the Electronic Warfare Officer Training Course. In 1986, Major Wright transferred to Headquarters Air Force Operational Test and Evaluation Center (AFOTEC), Kirtland AFB, New Mexico, where he was a lead analyst for several electronic combat (EC) system test programs. While at AFOTEC he developed operational effectiveness test approaches and data management and analysis plans for the evaluation of EC systems. In 1991 the commander selected him as AFOTEC's command-sponsored research fellow assigned to AUCADRE.

Major Wright holds a bachelor's degree in aeronautical engineering technology from Arizona State University and a master's degree in aeronautical science from Embry-Riddle Aeronautical University. He is a graduate of Squadron Officer School and Air Command and Staff College. A lieutenant colonel selectee, he is currently assigned as a test manager at Headquarters AFOTEC, Kirtland AFB. He and his wife, Elizabeth, have one daughter, Kaitlin.

Preface

In the mid- to late 1980s there was a proliferation of new threat systems being produced and deployed. This expansion weakened the Air Force's ability to successfully operate and support a weapon system in its intended operational environment. As a result, various new electronic combat (EC) system acquisition programs were started in addition to upgrades to existing EC systems. They were directed toward correcting deficiencies in our current capabilities to identify and counter the various threat systems.

Initially, EC systems were developed under a "quick-reaction" program that attempted to satisfy the immediate need of countering the enemy's threat system. Consequently, the test and evaluation (T&E) that took place ended up being more of a trial-and-error process. In recent years it has become apparent that these systems did not always work as desired despite the expense of developing and deploying them. This has led various levels of government to question why we can't produce an EC system that does the job as intended without requiring huge sums of money and an inordinate number of years to develop. This type of question and increased congressional scrutiny of EC system acquisition programs led to a broad area review of the EC acquisition process.

One of the findings from the review highlighted the fact that there is no standardized test process for EC systems like there is for aircraft. As a result, decision makers are not receiving the kind of information they need in making acquisition decisions. In addition, the Department of Defense (DOD) inspector general (IG) reviewed several operational test and evaluation (OT&E) programs and concluded that OT&E would have more impact on acquisition decisions if it did not get caught up in the "test-fix-test scenario" that began in developmental testing. As a consequence, the production of meaningful test results used by the decision makers to assess an EC system's operational effectiveness and suitability has not been completely satisfied.

Furthermore, there is a growing perception that OT&E has become an extension of developmental testing and cannot produce meaningful acquisition information for the decision makers. This is due in part to the limitations and challenges of evaluating the EC system's contribution to the overall success of the mission. Many of these limitations are caused by an inadequate operational test environment that is not representative of the actual threat environment. A test method must be developed to evaluate EC systems in a test environment that faithfully represents the actual operational environment. Additionally, the operational test agency (OTA) gets caught up in assessing or evaluating the performance of the EC system at a system

level instead of at the mission level. Decision makers want to know how effective the EC system is in contributing to the success of the mission. The OTAs must do a better job in establishing mission-level measures that reflect the EC system's contribution to the mission. With the proper application of the T&E tools, decision makers can get meaningful test results that will show the EC system's effectiveness in supporting the mission objectives.

This study analyzes the findings from the broad area and DOD IG's reviews, and it devises an EC test process that incorporates the principles of a scientific test methodology. Employing the methods associated with a scientific test process adds discipline and structure to the evaluation of EC systems with the intent of providing meaningful information to the decision makers. This is directed to those OTAs and individuals who are tasked to conduct OT&E of EC systems. It begins by reviewing the types of T&E and the different stages of operational testing, then many of the limitations and challenges to EC system testing are reported to call attention to the difficulties in testing EC systems.

To determine whether the EC system can indeed identify or counter the threat will require the generation of sufficient test data. This study describes the type of T&E tools needed to generate the test data as well as their purpose in supporting the EC test process. Following the description of the T&E tools are six steps that form the foundation for a scientific test process. The scientific test process can be applied to any stage of OT&E while incorporating the discipline and structure needed to evaluate the operational effectiveness and suitability test objectives.

Finally, it is important to understand the tasks that are accomplished in each phase of the acquisition process and how the EC test process supports the decision makers. The five phases of the acquisition process provide an excellent means to implement the EC test process. This study delineates each phase along with the responsibilities of the system program office and the OTA in supporting the acquisition of EC systems. In addition, it points out where and how the T&E tools can lend assistance to the operational assessment or evaluation in each phase of the acquisition process.

Implementing the recommendations in this study will structure an EC test process that will provide the discipline needed to overcome the limitations and challenges associated with testing EC systems. By using T&E tools properly and applying the methods related to the scientific test process, we can generate a reliable estimate of the operational effectiveness and suitability of EC systems at the mission level. The scientific test process will also help the OTAs avoid the test-fix-test scenario that began in developmental testing by preparing the tester for the evaluation and by reporting the results from the evaluation at the conclusion of the test process. Furthermore, the test process described in this study gives the decision makers meaningful information on which they can base their acquisition decisions and the confidence that the test results reflect the way the system will work if deployed. Adopting the

recommendations in this study will provide a cost-effective and efficient method to test EC systems. The outcome will be an EC system that will function in its intended operational environment and contribute to the overall success of the mission.

Frederick L. Wright

FREDERICK L. WRIGHT, Maj, USAF
Research Fellow
Airpower Research Institute

Acknowledgments

I would like to acknowledge several people without whose support and help I would never have gotten off the ground with this study. I want to thank Maj Gen Peter D. Robinson, former commander of AFOTEC, for selecting me to do the research into OT&E of EC systems. General Robinson understands the importance of OT&E and has recognized the fact that the current test process has not satisfied the needs of the decision authorities. I would like to thank Col Mike Douglas for his confidence and support during my time at Maxwell AFB, Alabama. My thanks also go to Mr Mike Stolle for reviewing the draft and providing comments to keep me on track as OT&E evolves to meet the needs of the acquisition process.

I want to especially thank Lt Col Mike Reich for the many discussions we had on EC system testing. His experience and insight into T&E of EC systems have been invaluable in helping me to eliminate inconsistencies in my study. I would like to thank Lt Col Roy Williams for the support he has given me in reviewing various portions of the document, especially in the area of T&E tools.

I am particularly grateful to my reading group chairman, Dr Lewis B. Ware, for getting me started and teaching me how to go about writing a research report. His suggestions improved both the organization and tone of the report while strengthening the importance of the EC test process. A special thanks to my editor, Ms Marion S. Gorrie, who enhanced the quality and readability of the study. I am most grateful for her fine work.

Most importantly, I want to express my sincere appreciation to my wife, Elizabeth, and daughter, Kaitlin, for their love and understanding during those times when I was struggling with this study. Their presence was very important to me and made all the difference in ensuring my success in completing this study.

Executive Summary

The current electronic combat (EC) test process lacks discipline and structure because there is no standardized operational test process used in evaluating EC systems. The purpose of this study is to describe a test process that incorporates discipline and structure into the operational test and evaluation (OT&E) of EC systems with the intent of providing needed information to the decision makers.

The failure of the test process for EC systems can be traced to several limitations and challenges. One of the limitations has to do with an inadequate field test environment that does not truly represent the operational environment. Additionally, the operational test agencies (OTA) face the challenge of establishing mission-level measures and coming up with evaluation criteria for those measures prior to the start of OT&E. Another limitation to the EC test process is the absence of complete intelligence on the threat systems. Finally, the OTAs do not have a method that reports the contribution toward mission success from an EC system that is integrated with and highly dependent on other on-board avionics. A test process must be developed that addresses these limitations and challenges.

In this study the author resolves these challenges by applying the proper mix of test and evaluation tools and by utilizing the methods associated with a scientific test process. The right mix and application of test tools can provide the decision makers with information regarding the EC system's effectiveness and suitability in an operationally representative environment at a mission level. This is accomplished by applying a scientific test methodology that provides the discipline and structure to the EC test process.

On the basis of the above, the author recommends that the OTAs (1) institute the scientific test process, (2) educate and train the appropriate personnel, and (3) clarify the requirements in AFR 55-43, *Management of Operational Test and Evaluation*.

This study is targeted to the OTAs, test teams, test managers, and members of the test support group who have been tasked to conduct OT&E of EC systems. It can be both a primer for someone new to the operational evaluation of EC systems or an essay for the professional tester. It provides a basic description of the T&E tools used to evaluate EC systems as well as a scientific test process that will add discipline and structure to the test process. In addition, this study gives the operational test manager and test teams some insight into the acquisition process, the responsibilities of those involved in testing EC systems, and the kind of information the decision makers are looking for at each milestone decision point.

Chapter 1

Introduction to Operational Test and Evaluation

Operational test and evaluation (OT&E) is an important part of the acquisition process. OT&E is testing conducted in as realistic an operational environment as practical to evaluate operational effectiveness and suitability objectives and to provide an estimate of the system's military utility. OT&E provides credible information to the Air Force and Department of Defense (DOD) decision makers who rely on OT&E findings at various program milestones. The findings contribute to decisions on the acquisition of new systems, or upgrades to existing systems, and to the status of their operational capabilities.

Testing prcvides the basis for an evaluation by obtaining, verifying, or producing data.[1] The evaluation furnishes a method to judge the system's achievement of required operational effectiveness and suitability objectives by analyzing quantitative and qualitative data derived from the test. The purpose of testing electronic combat (EC) systems is to see if they meet the using command's specific mission need or satisfy a deficiency in terms of critical operational issues.

As a result of OT&E identifying operational inadequacies in several EC systems, the Air Force initiated in October 1988 a broad area review to determine if there were deficiencies in the EC system acquisition process. The review concluded that EC testing lacks the discipline and essential elements of a scientific approach.[2] Because of the lack of discipline and structure in the test process, a perception has been created that the operational testing community cannot produce meaningful information for the decision makers. Another perception is that OT&E does not have the impact on the acquisition milestone decisions as envisioned by Congress.

The purpose of this study is to give the operational test agencies (OTA) a standardized test process that includes the discipline and structure of a scientific test approach and that can be applied to the OT&E of EC systems. The study describes the test and evaluation (T&E) tools that are available to the test manager and their application in the EC test process. It outlines the procedures for conducting an orderly scientific test process needed to test EC systems. The scientific test process will help overcome some of the limitations and challenges associated with the current EC test process. The study concludes by providing the test manager with a description of the information

afforded at each milestone point and how OT&E is used to support the acquisition process.

Having begun by defining the purpose of OT&E, this chapter defines the different stages of OT&E and where they fit into the framework of the acquisition process (fig. 1). Then the chapter discusses several limitations and challenges to effective OT&E along with two examples of where the current EC test process has broken down. Finally, the chapter concludes with statements made by the chief of staff of the Air Force (CSAF) on the EC acquisition process and points out several findings from an Air Force ad hoc group study on the EC test process.

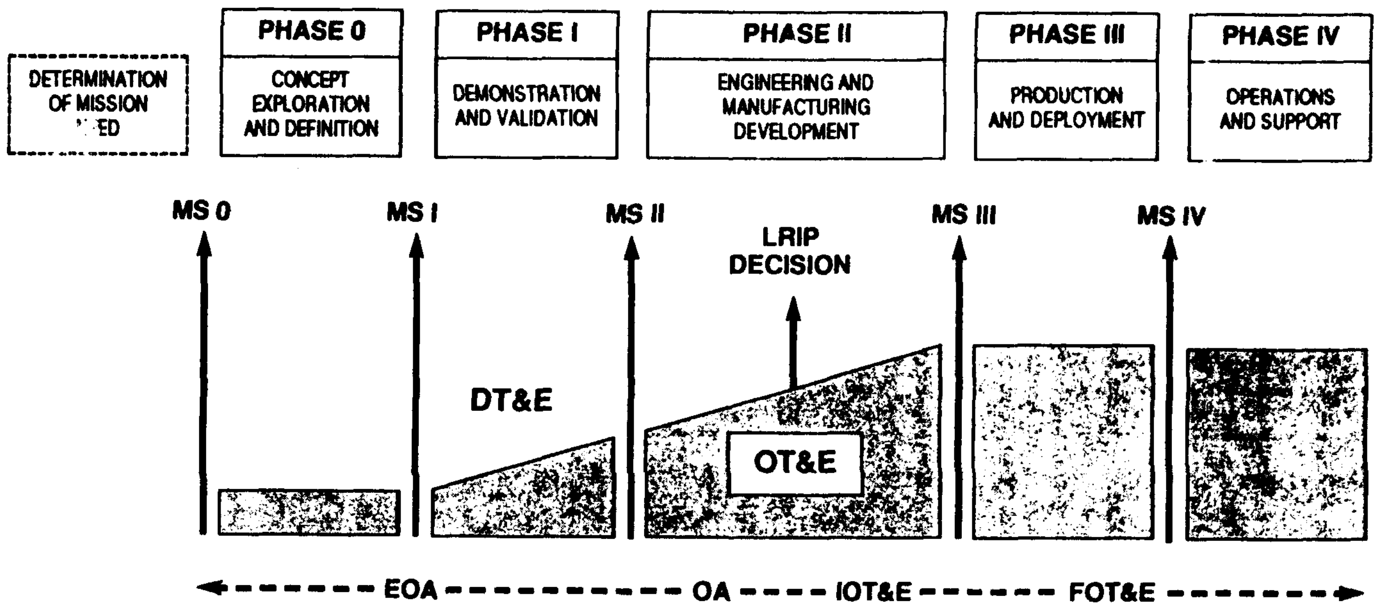
Types of Test and Evaluation

Testing is normally divided between developmental and operational events. Developmental test and evaluation (DT&E) and OT&E can occur in any phase of the acquisition process. Usually OT&E follows DT&E, but they may overlap or be combined. DT&E involves an engineering analysis of the system to ensure that it meets the design specifications and performance requirements and that it accomplishes the developmental objectives. DT&E is usually conducted by the developing contractor or system program office (SPO) in some type of controlled laboratory or field test environment with a single prototype system. Generally DT&E does not go much beyond testing an individual prototype system against a single threat system (one-versus-one), or at most in a one-versus-few test environment. As a result, the system's demonstrated performance at the end of developmental testing may not be truly representative of how it will perform in an operational environment.

Through OT&E, the OTAs will determine if the EC system's performance meets the user's operational requirements for combat or other mission needs. The Air Force's OTAs are tasked through the program management directive (PMD) to manage the independent OT&E of the electronic combat system.

Five major acquisition phases and milestone decision points (see fig. 1) provide a developmental framework to implement a process to ensure the EC system meets the user's operational requirements. Except for the beginning milestone, each milestone decision is supported by some type of operational assessment or evaluation. Decision makers rely on these assessments and evaluations to make knowledgeable decisions during each phase of the acquisition process. Furthermore, results from OT&E provide the confidence decision makers need in deciding whether the program should enter the next phase of the acquisition process.

Operational assessments and evaluations support the milestone decision points with information drawn from various sources. Depending on which acquisition phase the program is in and the nature of the test, these sources of information can include observing advanced developmental prototypes,



Legend:
MS = Milestone
DT&E = Developmental Test and Evaluation
OT&E = Operational Test and Evaluation
IOT&E = Initial Operational Test and Evaluation
LRIP = Low-Rate Initial Production
EOA = Early Operational Assessment
OA = Operational Assessment
FOT&E = Follow-On Operational Test and Evaluation

Source: AFR 55-43, *Management of Operational Test and Evaluation*, 29 June 1990, 6 (revised).

Figure 1. The Acquisition Phases and OT&E Stages

models, and simulations; using data obtained from modeling and simulation or from combined DT&E/OT&E testing; or analyzing data from dedicated OT&E. Whatever the source, the OTA must make sure that its conclusions truly report the capabilities of the system in terms of operational requirements.

An important part of the decision-making process for all acquisition programs is the cost/operational effectiveness analysis (COEA) process. Air Force Regulation (AFR) 57-1, *Air Force Mission Needs and Operational Requirements Process*, states that

> the COEA allows the MAJCOM/CC to make comparisons of alternative solutions on the basis of cost and operational effectiveness, documents analytical rationale for preferring one alternative over another, helps to justify the need for starting or continuing an acquisition program, and effectively communicates the decision at all levels in operations, cost, and acquisition communities.[3]

The major command (MAJCOM) responsible for the mission area that includes the identified deficiency or need will conduct concept studies, identify and evaluate potential alternative solutions, and prepare the COEA. The implementing, supporting, and participating commands and agencies will provide support to the MAJCOM in the COEA process as directed in the program management directive. The MAJCOM prepares a COEA for the milestone I and II decision points and updates the COEA for the other milestones as required.

The COEA is intended to aid decision makers in judging whether the alternatives offer sufficient military benefit to be worth the cost. The process will involve decision makers and staffs at all levels in the discussion of reasonable alternatives. The COEA process will also document the acquisition decisions by providing a record of the alternatives considered at each milestone decision point. A comprehensive T&E program places confidence in the key assumptions and estimates that go into the COEA. Results from testing then provide needed information for the COEA process as well as analyzing the operational effectiveness and suitability of the system.

In an effort to help reduce risk in early acquisition decisions, the DOD has instructed the OTAs to examine systems in the early stages of the acquisition process before there are any production-representative systems to test. The General Accounting Office (GAO) agrees with this philosophy and cites the following in its report to the chairman of the Senate Committee on Governmental Affairs:

> When OT&E is done before initial production [approval], information is available on potential shortcomings that would not be foreseen through developmental testing. Further, OT&E results permit decision makers to assess whether potentially costly modifications are needed.[4]

Therefore, early involvement by the OTAs can provide decision makers with additional knowledge to manage risk with key indicators provided through operational assessments and evaluations at each milestone.

If an OTA is involved in the concept exploration and definition phase to support a milestone I decision or during the demonstration and validation phase to support a milestone II decision, it is called an early operational assessment (EOA) (see fig. 1). When test activity supports a low rate initial production (LRIP) or similar decision before milestone III, it is known as an operational assessment (OA). EOAs and OAs provide the information to assess a system's potential capability to meet user requirements and the program's progress toward producing an operationally effective and suitable system.

However, it is of paramount importance that the decision makers not judge the performance of the system on the operational assessment alone. While a national security fellow at Harvard University, Col Robert Behler made a similar comment in his study, "Defense Acquisition in the Post Cold War Era," when describing the approach to an EOA.

> It is essential that the acquisition decision makers fully understand that an EOA [or OA] is not a substitute for dedicated Operational Test and Evaluation, only a tool for making prudent decisions early in the acquisition process. Only by gathering empirical data under realistic conditions will the actual operational capabilities of a system be understood.[5]

Operational assessments are generally intended to (1) review the status of program documentation, with emphasis on user requirements and testable criteria; (2) review test planning issues dealing with the schedule and resources; (3) highlight significant programmatic voids and trends that could impact the system's ability to meet user requirements; and (4) draw conclusions from limited field tests or simulations as directed.[6]

The purpose of the OA is not to critique DT&E but to comment on important trends identified during the assessment that could impact user requirements and to ensure that the user's operational concerns are addressed in the developmental process. An operational assessment provides a method for the operational test agency to interact with the user and developer early in the acquisition process to make sure operational requirements are clearly established and defined with meaningful OT&E criteria. OAs are based on all information relevant to the program, such as data from development testing, user trials, interim OT&E results, and modeling/simulation. For the OTAs, the main thrust of both the EOA and OA is to ensure that the test program is ready to enter the next phase of the OT&E.

It is during the engineering and manufacturing development phase that the test program enters initial operational test and evaluation (IOT&E) (see fig. 1). IOT&E begins as early as possible in this phase of the acquisition process and initially may be combined with developmental test and evaluation as they share the same prototype systems. The testing that is conducted on the preproduction systems or prototypes is designed to provide an estimate of the system's operational effectiveness and suitability. Many of the same re-

sources and T&E tools used in DT&E may be used in IOT&E. IOT&E concludes with a dedicated phase of testing using production or production-representative systems and is normally completed before the first major production decision (milestone III).

Follow-on operational test and evaluation (FOT&E) is normally conducted after the full-rate production decision has been made. In this final phase of OT&E, testing is conducted on production systems in an operational test environment. FOT&E is used to verify operational effectiveness and suitability results determined during IOT&E, to identify operational deficiencies, to evaluate system changes, or to reevaluate the system against changing operational needs.

The binding document that is used to plan, review, and approve the T&E process is the test and evaluation master plan (TEMP). It supports the acquisition process by depicting the overall structure and objectives of the test program. AFR 80-14, *Test and Evaluation*, states that "a TEMP is required for all HQ USAF programs directed by a program management directive (PMD)."[7] It identifies the critical issues, test objectives, evaluation criteria, system characteristics, responsibilities, resources, and schedules that form the framework for the T&E program.[8] A framework for T&E allows those issues associated with the test schedule and resource requirements to be resolved and the OT&E test plan developed. Either the SPO or an agency designated in the PMD will prepare the TEMP. The preparer will receive assistance from the participating, operating, and supporting commands and OTAs in developing and updating the TEMP as required.

Each stage of OT&E serves a specific purpose in the acquisition process. The earlier stages of OT&E furnish the developer and decision maker with information on the progress of the EC system in meeting operational requirements. It is also used to prepare for and plan the operational evaluation. The final stages of OT&E are designed to give the user and decision makers an estimate of how well the EC system met or did not meet the user's requirements.

OT&E has a responsibility in the early phases of the acquisition process to provide information on the EC system's potential in meeting the user's mission need. However, this creates quite a challenge to the OTAs because in most cases there are no production-representative systems available to test. In the later stages of OT&E, continual trade-offs made in the design and development of the EC system can delay fielding a system that is ready for dedicated operational testing. As a result, the amount and extent of operational testing that can be accomplished before the scheduled decision point are sometimes affected. Therefore, OT&E has not always been effective in estimating the performance of the EC system before the initial production decision is made. To field an EC system that meets the user's operational effectiveness and suitability requirements, these and other challenges to the EC test process must be overcome.

Challenges and Limitations

Most challenges to OT&E come in the form of limitations or shortfalls in evaluating an EC system in a field test environment that represents a realistic mission scenario. Historically, these challenges have influenced the EC test programs in different ways, but the end result is always the same—the perception that OT&E cannot produce meaningful test results and is nonsupportive of congressional intent. However, OT&E does identify inadequacies in the effectiveness and suitability of the EC systems tested. The problem is with the acquisition process, or more specifically, with the implementation of the EC test process rather than with OT&E in general. The General Accounting Office cites the following in its report to the Senate Committee on Governmental Affairs:

> [The] selection of test sites [has] not always been representative of operating environments, test objectives and evaluation criteria have not always been established, test resources have not always been available or adequate.[9]

To adequately test EC systems, improvements must be made in the test process to correct these limitations and shortfalls. Correcting these inadequacies will give the decision maker the knowledge to judge whether the system meets its operational effectiveness and suitability performance requirements.

Ideally, OT&E of electronic combat systems should be conducted in an unconstrained, realistic operational environment. This would provide the necessary test data to evaluate the effectiveness of the system in its intended environment and its suitability in the field. However, operational testing usually ends in a compromise between the ideal and the possible.[10]

OTAs are faced with testing the EC system in a field environment that is generally accepted by the decision maker as the best available, but still lacks that sense of true realism that the decision maker would like to see. However, to provide the realism and threat density representative of the operational environment many changes and improvements are needed to the field test ranges. And, although the test program is a small part of the total costs in acquiring a system, it still receives its share of scrutiny when it comes to allocating funds. Since the T&E infrastructure used to support the test program does not always receive adequate funding to facilitate needed improvements, testing is affected also. OTAs must look for ways to keep the cost of OT&E within reason, and they must accept the challenge of conducting realistic OT&E under various budget constraints.

Currently, the level of realism needed in the field cannot be achieved due to the scarcity and quality of the threat simulators. The result is a field test that evaluates the EC system's performance in a one-versus-one or at best one-versus-few scenario. Furthermore, because of the ever-increasing use of the electromagnetic spectrum in EC, field test ranges must provide a multispectral threat environment in which to test EC systems. However, generating a representative multispectral threat environment is difficult without a

substantial investment in test resources and range improvements. Even if there were unlimited funds to build and improve the field test ranges, it is still not possible to reproduce the operational scenario exactly. You cannot build an infrastructure to reflect every possible scenario combination and you cannot allow the test aircraft to be shot down by the threat systems. So, while the decision maker wants/desires as much realism as possible, achieving it is expensive, forcing trade-offs between satisfying the requirement for realistic operational testing and the costs in conducting the test.

In most cases, the OTAs are faced with the challenge of establishing operational test measures and evaluation criteria without an adequate mission statement. It is easy to obtain technical performance measures from contract specifications. But translating them into mission-level measures that describe the operational effectiveness of the EC system is a challenge that must be addressed through an improved EC test process.

Currently, the OTAs end up with measures of effectiveness that are very similar to the technical specifications used in developmental T&E, such as detection times and ranges, correct threat prioritization, threat identification, and threat-processing capabilities. Consequently, the decision makers have to base their acquisition decisions on results from technical performance measures instead of mission-level results. Meeting specifications does not guarantee that the system will perform in the operational environment as envisioned.[11]

Decision makers really want to know how the EC system supports the mission objectives in an operational environment and if it performs satisfactorily in this environment. The current EC test process does not go far enough in answering these kinds of questions. An improved EC test process may never be able to provide all the answers, but with mission-level measures and meaningful evaluation criteria, OT&E can provide some determination of how effective the system is and its suitability in an operational environment.

One of the challenges of developing and testing EC systems is the constantly evolving threat and the lag in gathering intelligence on the threat systems.[12] Developers and testers of EC systems must have specific and detailed intelligence on the threat systems they are likely to encounter in the wartime environment. In most cases, sufficient intelligence is not available as the design of the EC system proceeds. New threat intelligence dictates changes in the design of the EC system. As a result, additional development time is needed to incorporate this information into the system and to verify that any new technology needed to support the design changes will work. This makes the OTA's job of testing a production-representative system quite difficult because the developer is still refining the operation of the EC system to meet the latest threat at the expense of operational testing.

Another challenge to the OT&E of EC systems is the increasingly integrated nature of the avionics with the host aircraft.[13] EC systems are becoming more and more dependent on timely information from other sensors. They must be compatible with other onboard avionics and they must communicate with other hardware and software functions. This means the total

avionics suite must be up and functioning as designed for a complete evaluation of the EC system's contribution to the mission. This increase in integration further complicates the OTA's ability to test and evaluate the effectiveness and suitability of EC systems. This is due to the requirement for more representative test scenarios using both friendly and hostile players along with their associated command, control, and communications (C^3) network as well as a multispectral test environment. A totally integrated avionics package also makes it difficult to determine the contribution towards mission success from the EC system being tested or from other onboard avionics. These challenges to the OT&E of EC systems must be recognized and accounted for in an effort to provide representative test results to the decision makers.

Because of these limitations and the way EC test programs have been structured, several EC systems have failed to be developed adequately to meet the user's operational requirements. Two examples can be cited where EC systems were not adequately developed and tested before they proceeded into the next phase of the acquisition process. In the first example, the Airborne Self-Protection Jammer (ASPJ) was tested by the Air Force Operational Test and Evaluation Center (AFOTEC) and failed to meet several operational effectiveness and suitability objectives.

In this case, the failure of the system was due to a combination of factors. First, the system was in development for 10 years, during which time the threats it was designed to counter were replaced by later versions. Consequently, ASPJ could not counter the latest threats in the operational environment. Second, immature or unproven technologies were used in the design of the system. Because these technologies were not adequately tested early in the acquisition process, problems with the effectiveness and suitability of the system were not discovered until it began dedicated IOT&E.

In the second example, the B-1B defensive system was found to be quite limited in its ability to counter the threats in its projected mission scenario. Although this was a presidentially mandated program with the decision to produce the B-1B already made, the EC test process failed to identify problems with the defensive system in the early stages of the acquisition process.

Here again one of the problems was that new threats were being deployed at the same time the defensive system was being developed. This had a significant effect on the defensive system's ability to meet the user's changing requirements. But the greatest developmental failure had to be that the B-1B's defensive system was never fully tested in a hybrid ground test facility. The first real testing began in the field after the system was installed in the B-1B. Consequently, the system ended up in a fly-fix-fly development cycle that carried over to OT&E. OT&E was not able to break this cycle and ultimately ended up supporting the developers and not the acquisition process.

These two cases illustrate the lack of an adequate and disciplined test process in the early stages of the acquisition process. The proper tools needed

to support these programs were either not used or not in place when the system entered testing. In both cases, the OTA was relegated to a test-fix-test scenario that began during DT&E. As a result, OT&E did not provide the decision makers with what they were looking for to support program decisions.

Actions Taken to Correct the Problems

Because of these two EC systems and others failing to meet the needs of the user, CSAF Gen Larry Welch initiated a "broad area review" of the acquisition test process for EC systems. On 9 March 1988 the director of Strategic/Special Operations Forces (SOF)/Airlift Programs for the secretary of the Air Force (SAF/AQQ), Maj Gen Michael Hall, briefed the results of the broad area review which depicted the EC test process as lacking in structure and standardization.[14] This led General Welch to conclude that the acquisition process for EC systems was broken, that EC systems took too long to develop, cost too much, and do not always work. Further, Col Bob Senko, chief of the OT&E division at the Air Staff, reported that among other problems, the CSAF found that EC testing was at fault. Colonel Senko directed the Air Force Systems Command (AFSC) commander to host a group to determine how to obtain a logical test process and define a set of standard measures to determine the military worth of our EC acquisitions.[15]

On 10 October 1988, after examining the EC systems acquisition test process, the AFSC-led ad hoc group released its findings and recommendations in a report titled "Test Process for Electronic Combat Systems Development." It cited inadequate testing as one of the problems in the acquisition process for EC systems. The ad hoc group found that "an institutionalized, disciplined process such as that employed for aircraft and other weapon systems does not exist for the development and upgrades of EC systems."[16] It went on to say that

> the lack of an institutional test process manifests itself in our inability to produce meaningful information for decision makers to use in determining whether development/upgrades should proceed, and in the lack of discipline among programs as to what test resources should be used.[17]

In addition, a DOD Inspector General (IG) report titled "Operational Test and Evaluation within the Department of Defense" states that

> OT&E does not have the major impact envisioned by the Congress on acquisition milestone decisions that was intended by Congress. Instead of using OT&E results to delay or halt production of weapon systems with questionable effectiveness or suitability, acquisition executives use the results to continue the test-fix-test scenario begun during developmental testing. While productive in supporting the industrial base and ultimately delivering new weapon systems, the test-fix-test scenario does not meet congressional expectations for OT&E to support "go-no-go"

program decisions. Thus, the OT&E community is often criticized by the Congress and perceived as being nonsupportive of congressional intent.[18]

The findings from the ad hoc group and the DOD IG's report highlight the need to establish a disciplined process to acquire and test EC systems. Adding discipline and structure to the test process will also give the decision makers timely information to support production decisions.

Decision makers believe that the lack of a structured test and evaluation process has contributed to the problems and failures experienced in EC system development and upgrades. In a letter to all MAJCOMs and separate operating agencies (SOA) dated 7 November 1988, the chief of staff endorsed the ad hoc group's report and directed immediate implementation of their recommendations for a structured EC test process.[19] In essence, the chief of staff has tasked all Air Force organizations involved in developing, modifying, and testing EC systems to follow the recommendations outlined in the ad hoc group's report. Implementation of the ad hoc group's recommendations would provide a structured process characteristic of a scientific test approach. Key elements to the scientific test approach include generating the test requirements, pretest planning, carrying out the test, analyzing and evaluating the results, and feeding back the test results to validate and refine models and simulations. This will ensure a disciplined approach to developing and fielding EC systems. It will also help the OTA structure a test program that will avoid the test-fix-test scenario by preparing the OTAs for the evaluation and by reporting the results of testing to decision makers in a timely manner.

Notes

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2. United States Air Force Ad Hoc Group, *Test Process for Electronic Combat Systems Development*, vol. 3, *References* (U) (Andrews AFB, Washington, D.C.: AFSC/TE, 10 October 1988), 14. (Secret) Information extracted is unclassified.
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5. Col Robert F. Behler, "Defense Acquisition in the Post Cold War Era," National Security Program Discussion Paper Series 91-02 (Cambridge, Mass.: John F. Kennedy School of Government, Harvard University, 1991), 48.
6. AFR 55-43, *Management of Operational Test and Evaluation*, 29 June 1990, 64.
7. AFR 80-14, 5.
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10. Lawrence R. Benson, *Test Limitations: Experience of the Air Force Operational Test and Evaluation Center (AFOTEC) 1974–1990*, pt. 1, *Analysis* (Kirtland AFB, N.Mex.: June 1991), ii.
11. Capt William D. Farmer and Col John F. Nagel, "Electronic Warfare System Operational Test and Evaluation," final report (Kirtland AFB, N.Mex.: Air Force Test and Evaluation Center, March 1980), 7.

12. Ad Hoc Group, vol. 2, *Report and Appendices*, 7.

13. Ibid.

14. Ibid., 1.

15. Briefing, Col Bob Senko, subject: Results of the Ad Hoc Group Examination of the Electronic Combat Systems Acquisition Test Process, undated.

16. Ad Hoc Group, vol. 1, *Executive Overview*, 1.

17. Ibid.

18. Department of Defense, "Operational Test and Evaluation within the Department of Defense: Inspection Report" (Arlington, Va.: Inspector General, 24 May 1991), i.

19. Gen Larry D. Welch, chief of staff, Headquarters USAF, to All MAJCOMs and SOAs, letter, subject: Test Process for Electronic Combat (EC) Systems Development, 7 November 1988.

Chapter 2

Test and Evaluation Tools

Before outlining a structured electronic combat (EC) test process, it is important to describe the test and evaluation (T&E) tools used to generate the data needed to perform an evaluation or assessment. The test manager must be familiar with the various types of T&E tools that are available, their purpose, and how they support the EC test process. In addition, the test manager must be aware of the assets and liabilities associated with each test tool in order to select the proper mix of T&E tools for the evaluation.

This chapter begins by describing the most common types of T&E tools used to support operational test and evaluation of EC systems. These tools can be grouped into three major categories: modeling and simulation (M/S), hybrid ground test facilities (GTF), and field test ranges. The advantages and disadvantages of each tool are discussed as well as their use in supporting OT&E. Of great importance to the decision maker is knowing that the test results truly represent the capabilities of the EC system. To provide this certainty in the test results, the T&E tools must go through a process that verifies, validates, and accredits their use in the EC test process. This process is examined following the discussion on the T&E tools. The chapter concludes with a comparison of the strengths and weaknesses of each tool and considerations in selecting the appropriate test tool(s) for the evaluation.

Modeling and Simulation

The first type of tool to consider in the EC test process is modeling and simulation. Models and simulations provide a method to augment or extend those areas that cannot be evaluated or assessed through field testing. They can overcome some of the limitations associated with field testing, such as the lack of adequate threat resources or a field-test environment that is not representative of an operational mission, and can easily accommodate intelligence updates to the threat definitions. M/S can also be used to aid in the development of mission-level measures and evaluation criteria, lessen the impact of budget constraints, and support early involvement by the OTA in the acquisition process. Dr Patricia Sanders is responsible for policy concerning the use of M/S at the Office of the Secretary of Defense (OSD). She describes models and simulations as

tools that can potentially augment and/or complement actual field tests and provide decision makers necessary information to assess the progress of a system toward fulfilling the operational needs. . . . Consequently, it is appropriate to use M/S as an aid to OT&E planning, as an evaluation tool prior to the availability of a complete system, and to augment, extend, or enhance actual field test results.[1]

Models and simulations will not replace field testing, but they can supplement it by providing the ability to expand the operational evaluation or assessment to those areas where operational realism cannot be obtained in the field. On the other hand, using M/S to complement field testing will be at the cost of increasing some "risk" to the evaluation because the results from M/S may not give a complete picture of the system's capabilities. Even when validated or accredited, M/S will generally yield higher risk and less confidence than field testing.

A model represents a system by simulating the operating logic, process, rules, techniques, and methods of a system through a computer program. Models aid in understanding or evaluating the operation and behavior of a system. They can give the decision maker an idea of how well the system will perform its job in combination with other friendly systems—the intended host aircraft—and in an operational environment made up of threat systems. DOD 5000.2-M, *Defense Acquisition Management Documentation and Reports*, maintains that

the models used can take a variety of forms, from simple "stubby pencil calculations" to elegant mathematical formulations to large force-on-force computer simulations. Clearly, the type of model most useful for an analysis depends on the purpose being served.[2]

The process of implementing a model is called simulation. Simulations will allow the examination of a system's behavior under selected conditions. They can often demonstrate the operating functions or logic process when the system cannot be subjected to direct testing in the field. As opposed to field testing, simulations can provide a much broader range of data for evaluation at a reduced cost. For purposes of this study, the terms *modeling* and *simulation* are often interchangeable in the context of their use when supporting the EC test process.

Models and simulations range from those that describe specific events to those that generalize the combined effects of many systems in a large operational scenario. They are organized by their complexity and potential for analyzing a system's contribution to combat operations. Models are generally divided into four levels (table 1). An engineering-level model examines the technical performance of individual subsystems or techniques against distinct variables. Commonly referred to as a level I model, its one-versus-one engagements are the most detailed of the models. A level II or platform-level model examines the combined interactions of an aircraft's integrated avionics against several threat systems with the application of doctrine and tactics.

Table 1

Levels of Models

Level	*Short Name*	*Evaluation Focus*
I	Engineering	EC System Performance
II	Platform	Weapon System Engagement Effectiveness
III	Mission	Weapon System Employment Effectiveness
IV	Campaign	Force Effectiveness

Source: *Air Force Electronic Combat Development Test Process Guide* (Washington, D.C.: Department of the Air Force, 1 May 1991), 27. (Revised by author)

The output from a platform-level model represents an analysis of the system's effectiveness when engaged with a few threat systems. A level III model examines the mission effectiveness and suitability of a composite force opposing many threats. Doctrine and tactics for both friendly and hostile forces are applied in this mission-level analysis to determine the actions and reactions by all the forces. The level IV or campaign-level model examines the outcome of a projected theater war. Level IV models incorporate joint operations from the Army, Air Force, and Navy, as required, in the campaign against a theater-level force. They are the most complex and provide analysis at the strategic, policy, and force-planning levels. In most cases the results from lower-level models can be fed into the next higher-level model to support its analysis of the EC system's effectiveness and suitability.

In selecting a model, the test planner should consider the complexity or detail needed to address a specific question. The model should not be more complex than is absolutely required. Decisions concerning the selection and development of a model should include the user, developer, and tester early in the development of the EC system. A plan should be developed early on in the acquisition process that outlines the use, level of detail, and the upkeep for the model. This plan should show the transition and growth of the model from the initial phase of the acquisition program to its use in supporting the milestone III decision and beyond. To support the analysis of the EC system, the M/S plan must include a process that shows how the model will be updated, verified, and accredited for a specific purpose with field test results. By having an M/S plan in place, the process of planning, executing, and reporting the development and use of M/S will help provide credible results to decision makers.[3]

To lend acceptance to the results, the models and simulations must be verified, validated, or accredited with help from the intelligence community and field test results. Without a verified, validated, or accredited model or simulation, the test manager will have a tough time defending the use of M/S

in addressing the critical operational issues (COI). The reason for this is that decision makers are looking for confidence that conclusions drawn from M/S are credible and that valid conclusions can be formed about the effectiveness of the actual system.

The advantage of a model is that it can be run many times while simulating a variety of operational conditions, thus accelerating the analysis of the EC system. Because M/S can supplement field results, they help reduce the number of test missions or weapons expended in the field. This can save having to pay for expensive field range time or resources. Of course, there are some disadvantages in the use of M/S. Models and simulations can be expensive to develop, operate, maintain, and validate or accredit. If not validated or accredited, the decision maker may lack confidence in the output, thereby degrading the tests usefulness. But even if the models are validated or accredited, they can never provide the same level of confidence in the results as could be obtained through field tests. Models and simulations can require long lead times to develop and acquire. They can be manpower intensive when in operation, and they may not support all the test objectives. The test manager will have to keep these advantages and disadvantages in mind when determining the proper mix of M/S tools.

Simulations are often used during the early development phases of the acquisition process to support the evolution of the EC system and to determine mission-level requirements. During the early design stages, engineering- and platform-level models can be used to assist the developers in translating mission-level requirements into system specifications.[4] A system's mission-level requirements are identified through concept studies by the MAJCOM that has the responsibility for the specific mission area.

Because it is not likely that any representative hardware or software would be available during an early operational assessment, M/S can support an EOA by assessing the system's performance in the planned operational scenario. A digital computer model of the EC system can be designed from the initial system design specifications and used to assess its performance in the intended operational environment. Such a model could examine those critical operational mission requirements essential to the EC system's effectiveness and suitability.

To support the cost and operational effectiveness analysis process, M/S can be used in assisting the MAJCOM in studying alternative concepts that satisfy the mission need. Models can estimate the performance of a particular system in accomplishing the mission objectives. The COEA process can also benefit from M/S by using models to help establish the design and cost objectives before the milestone II decision. It will be up to the MAJCOM responsible for the COEA to use the same models or updated versions in each phase of the acquisition process to perform an analysis of the alternatives, document the results from the cost analysis of various alternative solutions, and update the life-cycle costs.

As an analytical tool, M/S will help ensure that the COIs are adequately addressed and resolved by the end of testing.[5] Models and simulations support pretest planning in the following areas:

- Extrapolating measures of effectiveness (MOE) from mission-level test objectives.
- Identifying important test parameters or elements to the test plan.
- Determining sensitivities to various input variables.
- Characterizing the operational test environment.
- Determining test resource requirements.
- Assessing the impact of range resource limitations.
- Refining the test scenarios.
- Identifying the required data elements used to support the evaluation.
- Prerunning the field test scenario.
- Structuring those flight test conditions that are the most important to evaluate in the field.
- Predicting potential outcomes which can be used to verify test procedures and results before the test is conducted on the range.

During the posttest evaluation, M/S can complement results from field testing by extending known parameters and actual test data to other operational scenarios. Also, by integrating actual test measurements into mission- or campaign-level models, M/S can extend test results to address MOEs that cannot be determined directly from field testing. If the EC test process incorporates the use of M/S to augment, extend, or enhance field testing, a balanced blend of M/S and field testing must be obtained.

The Hybrid Ground Test Facility

Ideally, OT&E would strictly use field test ranges to evaluate the effectiveness and suitability of actual or production-representative systems. Because of the difficulty of subjecting the EC system to a representative threat environment in the field, a complete picture of the system's performance capabilities cannot be ascertained. However, a hybrid ground test facility can contribute significantly to the evaluation of EC systems by providing a method to test their performance in representative threat environments.

A hybrid GTF can be described as a secure indoor facility that uses hardware and software to simulate the tracking, guidance, and communications associated with threat systems. Computer-driven threat replicas or simulators generate the representative radio frequency (RF), infrared (IR), millimeter wave (MMW), and laser emissions from threat systems for integration into a representative threat environment. By installing an actual EC system in a hybrid GTF (fig. 2) and using a computer to simulate the system's host aircraft, testers can analyze a simulated operational mission. Whether it

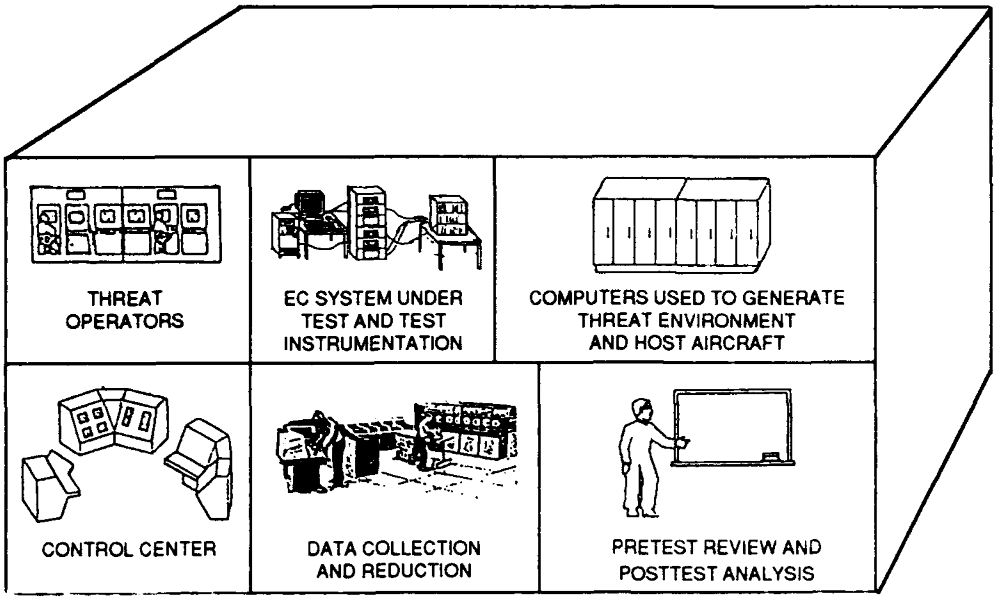

Figure 2. Uninstalled Ground Test Facility

is through coaxial cables, waveguides, or free-space radiation, signal propagation between the EC system and threat simulators can be controlled so that the emissions correctly include the effects of range, aircraft movement, scanning antennas, and other factors that appear in a real threat environment.[6]

To add a little more realism to the simulation, human operators can interface with the threat simulators through functionally correct controls and displays. This will close the action-reaction loop between the EC system and threat simulator. This type of simulation is referred to as closed-loop simulation (an open-loop simulation has no interaction with a human operator). A closed-loop threat simulator allows for real-time interaction between the simulator operator and the EC system. By installing EC systems in this facility and stimulating them either through digital connections or with actual free-space radiation, the tester can then evaluate the EC system's responses to this stimulation. This whole process is referred to as hardware-in-the-loop (HITL) simulation. HITL simulation allows the functional operation of the EC system under test to interact with a computer-controlled simulation of a representative threat environment.

To conduct the test, the hybrid GTFs require certain types of data as inputs to the simulation. This data includes the flight path through the operational environment; the host aircraft's radar cross section (RCS); a definition of the EC system; antenna patterns; and such threat site data as the location of the threats, the threat parameters, the rules of engagement, and so forth.[7] In addition, some hybrid GTFs must have the static and in-flight RF and IR measurements from the host aircraft as well as the antenna pattern measure-

ments from the onboard emitters and receivers to incorporate into the simulation.[8]

The instrumentation requirements in a hybrid GTF are tailored to the specific program objectives and desired output products. Data is collected through several devices such as magnetic tapes, paper tapes, strip chart recordings, and computer printouts.[9] Instrumentation software reduces the raw simulation data and performs statistical analysis on the results. The data products produced in the hybrid GTF include target range, jammer-to-signal ratios, tracking errors, and missile miss distance information.

There are different types and capabilities of hybrid GTFs from which a test manager will have to choose. Each facility has shortfalls or limitations of one kind or another. Hybrid GTFs vary in capability with the number and type of threats that can be generated, fidelity of the threat signals, and the various portions of the frequency spectrum that can be replicated. Some facilities can allow testing of actual or production-representative EC systems only when the system is not installed in or on their host aircraft (see fig. 2). Other hybrid GTFs provide a capability to test with the EC system installed in its host aircraft (fig. 3). These facilities provide a more representative indication of how the EC system functions while integrated with the operation of the other onboard avionic systems.

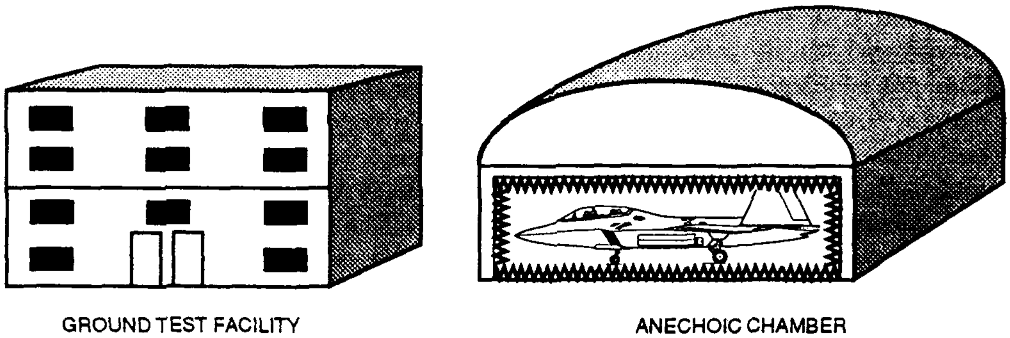

Figure 3. Installed Ground Test Facility

The main advantage of an uninstalled hybrid GTF is that it gives the tester an opportunity (usually the first) to evaluate EC systems before they are installed on or mounted in their host aircraft. This is useful when it is just the performance of the EC system that is being developed or evaluated and there is no concern for the integration with the host aircraft. Another advantage of testing only the EC system is that tests can be conducted when the host aircraft may not be ready to accept the EC system, or when the interface hardware and software between the host aircraft and EC system may not be ready for integrated testing.

The disadvantage of uninstalled hybrid GTFs is that they are limited in their ability to evaluate the integrated performance of the EC system with the host aircraft's avionic systems. Without the total avionic package, the tester

cannot assess any electromagnetic interference (EMI) or electromagnetic compatibility (EMC) problems between the EC system and the onboard avionic systems. Also, the uninstalled hybrid GTF does not lend itself well to evaluating the coupling of free-space radiation to the EC system sensors and assessing their performance. Uninstalled hybrid GTFs cannot factor in genuine environmental effects associated with open-air test ranges, such as terrain effects, meteorological conditions, or atmospheric effects. Furthermore, some of the uninstalled hybrid GTFs have no way to factor the aircrew member into the evaluation. Examples of uninstalled ground test facilities are the Air Force electronic warfare evaluation simulator (AFEWES), the real-time electromagnetic digitally controlled analyzer and processor (REDCAP), and the Guided Weapons Evaluation Facility (GWEF).

On the other hand, installed hybrid GTFs provide the added capability to evaluate EC systems installed on and integrated with their host platforms. This type of test facility can include an anechoic chamber large enough to accommodate a full-scale aircraft with its EC system and avionic systems installed (see fig. 3). The anechoic chamber would be linked to the test facility with cables to provide mission control and data collection. Free-space radiation can then take place in this chamber so testers can evaluate the integrated avionic system's responses and performance to this stimulation. An installed hybrid GTF can also consist of a facility where antenna hats are placed over the EC system's sensors on a parked aircraft. This type of facility does not require an anechoic chamber for free-space radiation of threat emissions. Virtually any kind of hostile or friendly RF emission can be generated with the use of signal generators. Using a computer to control the generation and radiation of RF emissions, testers can move transmissions representing the signals of interest around the aircraft to make it appear to the EC system sensors that the aircraft is flying through an operational scenario. The result is that the EC system responds to the threat stimulation as if it were actually flying through a threat environment.

Other advantages of the installed hybrid GTF are to save time and money by identifying system performance problems and providing a preflight and postflight checkout of the aircraft's avionics. These checkouts allow the tester to be sure the EC system is functioning properly before and after the test flight. An installed test facility can be used to determine if there are any EMI or EMC problems between the onboard avionics that would interfere with the planned test events. By noting any EMI or EMC problems, the tester can modify the scheduled test event to accomplish some other objective or delay the flight in order to resolve any problems.

There are disadvantages to installed hybrid GTFs. The first is a technical problem associated with free-space radiation in the anechoic chamber. Due to the size of the anechoic chamber, allowances must be made for the near- and far-field RF wave propagation effects and for suppressing any reflected energy. Furthermore, because the aircraft is not actually in free flight, target

dynamics must be factored into the evaluation and proper aperture polarization concessions must be made as the signals are moved around the aircraft. By using antenna hats, a ground test facility can solve the distorted RF wave patterns, but such devices do not allow evaluation of fuselage-masking effects. Currently, installed hybrid GTFs cannot provide the multispectral threat environment needed to test the performance of all sensor systems. Also, installed hybrid GTFs do not simulate very well the effects of terrain, meteorological, or atmospheric conditions. These facilities mainly employ open-loop threat simulators, thus leaving the human operator out of the equation. Examples of installed test facilities include the Preflight Integration of Munitions and Electronic Systems (PRIMES) at Eglin AFB, Florida; the Navy's Air Combat Environment Test and Evaluation Facility (ACETEF) at Patuxent River, Maryland; and the Avionics Test and Integration Complex (ATIC) at Edwards AFB, California.

An aircrew member can be factored into the simulation by linking the aircraft in the anechoic chamber or the computer-generated host aircraft in an uninstalled hybrid GTF, to a manned flight simulator that represents the actual aircraft cockpit controls and displays. This type of simulation is referred to as a man-in-the-loop (MITL) simulation (fig. 4). MITL simulation will allow a flight crew to fly a simulated mission through the computer-generated threat environment and respond with appropriate countermeasures and tactics as the scenario unfolds. By adding the aircrew member to the

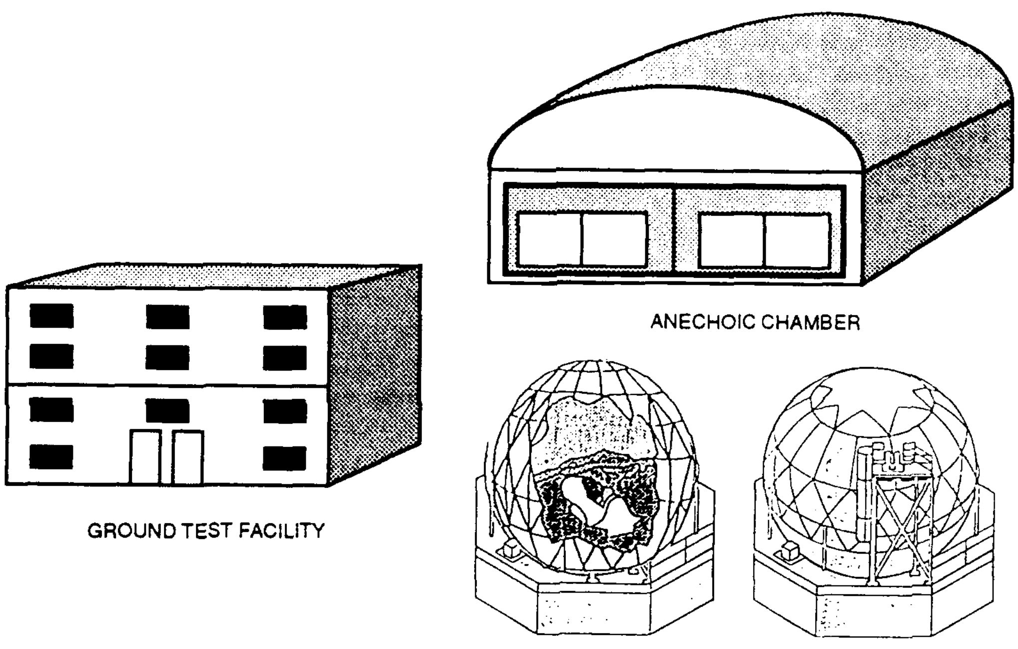

Figure 4. Man-in-the-Loop Simulation

evaluation, one can assess the man/machine interface and add a little more realism to the operational evaluation.

Hybrid GTFs are important tools that can complement field testing for those areas that cannot be evaluated in the field. They can supplement field testing by providing complementary data and a means to evaluate the effectiveness of the EC system. Hybrid GTFs can provide controlled and repeatable test conditions as needed to satisfy the data collection requirements. Hybrid GTFs can overcome some of the limitations and shortfalls associated with field testing such as cost, security, safety, airspace and frequency restrictions, a realistic operational threat environment, a limited number of test articles, and field range instrumentation.

Another advantage of hybrid GTFs is that they can overcome the shortage of fielded threat simulators by providing a dense signal environment to evaluate the EC system's performance. Hybrid GTFs can be cost-effective because it is impractical to replicate in the field all aspects of an operational environment due to the cost to build, install, and maintain the required number of threat simulators.[10] In addition, George Nicholas states in his article, "The EW Testing and Evaluation Quandary," that "we cannot afford to assemble all the test assets [hostile and friendly] necessary to conduct the required massive test exercises in the field."[11] Therefore, hybrid GTFs become important tools when bridging the gap between a representative operational environment and the shortages of fielded threat simulators. By being able to generate the anticipated signal densities of a representative operational environment, the tester can evaluate the EC system's ability to detect, identify, and process threat signals and their modes of operation. Hybrid GTFs can provide a dynamic simulated combat environment that represents an integrated air defense system. They can provide a method to evaluate the effects of hostile and friendly interaction, the EC system's response to the threat, and the system's susceptibility to electronic countermeasures by both hostile and friendly forces.

EC systems are also becoming more and more capable of monitoring and exploiting the RF, IR, MMW, and laser emissions from threat systems, as well as processing huge amounts of sensory data. From this data an accurate picture of the operational environment can be made by displaying the location of both hostile and friendly forces to the aircrew. It is this task of processing and assessing large amounts of sensory data in real time that presents the greatest challenge to the EC system. A hybrid GTF can significantly aid in the evaluation of the EC system by providing a realistic multispectral threat environment to test the performance of the system in fusing and correlating the sensory data, displaying it to the aircrew, and, if appropriate, initiating a countermeasure.

Hybrid GTFs provide opportunities to test against secure features or advanced threat systems where restrictions may exist in the field. They can provide a secure environment to test highly classified systems and to evaluate capabilities against hostile data links and the enemy's C^3 network.

As with M/S, hybrid GTFs can support the overall EC test process with prefield testing. The test manager can identify important test parameters or elements and determine their sensitivity to various field conditions. Hybrid GTFs can also help in the refinement of field instrumentation requirements and the data-reduction and analysis techniques, and can assess the employment of various tactics. In essence, the test manager can use hybrid GTFs to assist in refining the test plan to make more efficient use of available field range time.

Depending on the EC test program, a hybrid GTF can provide the tester with several advantages over field testing. It will be up to the test manager to clearly understand the test requirements before selecting the facility that best satisfies the test objectives. Although results from hybrid GTFs have more credibility than models, the threat simulators still need to go through a validation or accreditation process to ensure credible results.

Field Test Range

The final tool the test manager needs to consider in the EC test process is the field test range (fig. 5). Here the EC system is taken into the field to evaluate or assess its performance in addressing the operational effectiveness and suitability test objectives. Field testing provides the most credible data for OT&E. It gives the decision maker the opportunity to see how the system will function in its intended environment.

Field test ranges provide a test environment that comes close to a battlefield operational environment with actual people and hardware. They subject test articles to a comprehensive, integrated array of threat systems and the doctrine governing how those systems would be used by the enemy. Field test ranges are made up of realistic replicas of enemy equipment and a network of C^3 systems, as well as tracking systems, instrumentation and data-collection systems, and the necessary command and control network needed to conduct a successful evaluation. They will also employ enemy tactics and doctrine to make the test as representative as possible. Field test ranges include the key aspects of friendly forces attacking or penetrating the enemy's integrated air defense network. They give the tester an open-air environment for evaluating the EC system that M/S and hybrid GTFs cannot provide. However, to conduct an operational evaluation in the field requires the use of all available threat simulator resources, range assets, and range instrumentation systems to generate the best possible, operationally representative test scenario.

Evaluating EC systems in the field environment provides the decision maker with genuine results that can come only from an open-air environment. Field testing eliminates many of the disadvantages associated with a hybrid

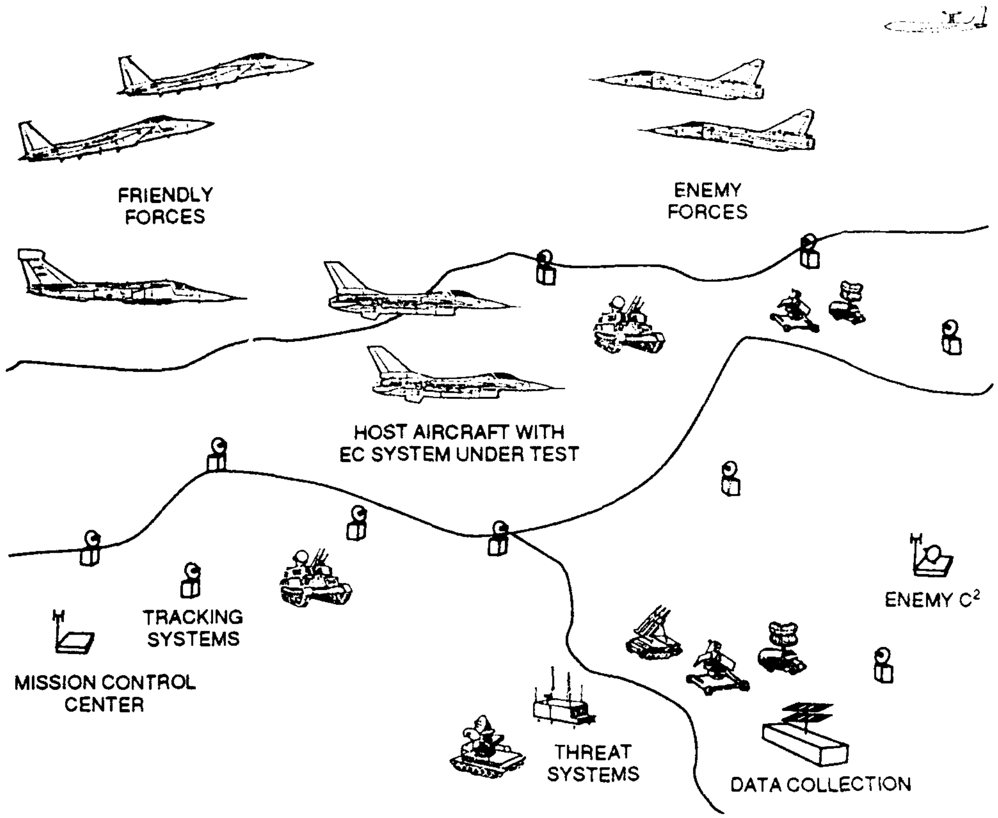

Figure 5. Field Test Range

GTF, such as terrain effects or not being able to factor in the aircrew member's decisions. Field testing can provide the data to calibrate the digital models and to validate and accredit the threat simulators in the hybrid GTFs. Field test ranges do not have the technical problems associated with free-space radiation as in an anechoic chamber. Testing in the field gives the added benefit of a complete end-to-end evaluation from the sensor to the aircrew member's display in a dynamic test environment.

Field test ranges have the advantages of examining certain effects that cannot be adequately accounted for with digital M/S or hybrid GTFs. These effects include

- atmospheric attenuation and ducting,
- meteorological conditions (wind, rain, dust, etc.),
- aircrew interaction in the test to include time-critical mission decisions,
- system interactions on the host aircraft and other aircraft or resources,
- terrain effects on RF propagation,
- interference with other aircraft in close proximity,

- aircraft structural masking of sensors, and
- actual antenna patterns and gains for each antenna or aperture.

Field testing can also have the advantage of discovering certain effects about the performance of the system that may have been dismissed as negligible or unimportant to the modelers.

However, Lt Col Greg Mann states in his research report, *The Role of Simulation of Operational Test and Evaluation*, that there are disadvantages to field testing.

> It may not be feasible to test all aspects of the weapon's capabilities because of range restrictions, instrumentation, safety constraints, and so on. It is difficult to maintain the same operating conditions for each replication or test. It is time consuming and costly to obtain the small sample size and therefore have statistical significance. It may be impossible to evaluate all or even nominal test conditions or test points in the field tests.[12]

Other disadvantages to the field test range are the lack in numbers of representative threat simulators and the associated C^3 network. Also, the field test range cannot keep up with the deployment of the latest threat systems because it takes years to gather enough intelligence to build a replica of the threat system, and it takes money. Another limitation to field test ranges is that the location and laydown of the threat simulators are not representative of the operational environment.

As is the case with ground test facilities, there are many field test ranges to choose from, depending on the type and capabilities needed for making the evaluation. Examples of field test ranges include the Electromagnetic Test Environment (EMTE) at Eglin AFB, Florida, and the Naval Air Warfare Center at China Lake, California.

Depending on the test, many of the same objectives that were evaluated in the hybrid GTF can be evaluated on the field test range. However, to complete the evaluation of the test objectives in the field, the test ranges have to be highly instrumented in order to generate the necessary data. Sources of range data include the manned threat simulators as well as a time-space-position information (TSPI) system used to keep track of the aircraft over the range. This data is recorded on magnetic tape to reconstruct a time history of the test scenario. Additional data-collecting devices used to record the test events and conditions during the conduct of the test include video tapes, voice recordings, and operator logs.

Field tests produce data in terms of target detection, missile-firing opportunities, firing results, and system reliabilities. They also yield data that includes weapon release signals from aircraft, launch signals from surface-to-air missile threat systems, the threat's mode of operation, and the threat's tracking quality on the target. By properly structuring the test, testers can use data from field test ranges to verify previous ground testing. Data can also be used to validate and accredit the results from the threat models used in the simulations and the threat simulators in the hybrid GTFs, or refine

their operation. Furthermore, correlating data from the flight test ranges with the models and the threat simulators can improve confidence in the test results obtained from M/S and hybrid GTFs.

Testing in the field allows the tester to address interoperability between various weapon systems and to test the efficiency of the man/machine interface. Hybrid GTFs can provide a good first look at the EC system in operation; however, they cannot reproduce the combat stresses associated with a real operational environment for both man and machine. Working under the stress of combat conditions, the aircrew members' decisions and reactions can be factored into the overall effectiveness of the EC system.

But the main purpose of the field test range is to evaluate the operational effectiveness and suitability of the EC system in an open-air environment. By conducting an operational evaluation of the EC system in a field test environment, testers can give the decision makers an indication of how effective it will be in supporting the user's mission need. Evaluating EC systems in the field environment provides tremendous credibility to the evaluation.

In addition to the effectiveness issues, there are the issues associated with weapon system suitability that can be adequately evaluated only in the field environment. The reason for this is that field testing permits the evaluation of a totally integrated weapon system functioning as it would in the operational environment.

Verification, Validation, and Accreditation

Models, simulations, and threat simulators all represent actual systems and their operating environments within the confines of a computer or system replica. However, to be an effective analysis tool in the EC test process, each model, simulation, and threat simulator must go through a verification, validation, and accreditation (VV&A) process to identify the differences between the model and the actual system. The following discussion is presented in terms of a model, but it can apply to simulations and threat simulators as well.

There are many definitions used to describe verification, validation, and accreditation. This study offers the following definitions for these terms as proposed during the 17 October 1990 Military Operations Research Society's symposium. *Verification* is "the process of determining that a model implementation accurately represents the developer's conceptual description and specification."[13] Simply stated, verification is a process used to ensure that the model behaves as designed and that the internal data, structure, and logic that represent the system are being modeled correctly.[14] Verification makes no assertion about the behavior of the model as compared to the real system. *Validation* is "the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended

uses of the model."[15] Validation is a process that tests "the agreement between the behavior of a simulation model and the observed behavior of a real system."[16] But validation is more than just agreement between the model and the real system, it must build confidence that the model actually represents the real system. In his thesis "Toward Validation of Computer Simulation Models in Operational Test and Evaluation," Capt James Arnett expands the definition of validation in terms of OT&E to include "the process of building an acceptable level of confidence that the simulated data agrees with the real data closely enough that an inference about the simulation is a valid inference about the actual system."[17] Moreover, validation is an ongoing process of building confidence in the model to a satisfactory level. It requires that over time one can measure and observe the same results from the model against a known baseline of performance (e.g., threat-detection range). And finally, *accreditation* is "the official determination that a model is acceptable for a specific purpose."[18] Accreditation requires that the model must meet specified measures of performance, provide confidence that the model will perform as designed, and be consistent over a wide range of operation for its specific purpose.

The test manager must ensure that any anticipated use or development of M/S for OT&E is documented in the test and evaluation master plan (TEMP) and OT&E test plan, with references to a process for verifying, validating, or accrediting the models used. Verification of models begins by making sure that the builder of the model is provided with the characteristics and parameters of the threat as described in the threat description document (TDD). Also a clear statement of the modeling requirements is essential if verification is to occur. After verifying that the model behaves the way it was designed, the test manager can use data from hybrid GTFs or field testing to validate the model. Hybrid GTFs provide a good source of data to validate the results from models, whereas field testing will provide the best source of data to validate the results from threat simulators in the hybrid GTFs. The threat simulators used in the hybrid GTFs and on the field test ranges will be validated by a separate agency responsible for simulator validation.

The process of validating is much more difficult than verifying the design of the model. For various reasons there will probably always be differences between the model and the actual system. But what is vital is understanding the impacts of those differences and making sure they are documented. The validation process requires comparing model results with results from hybrid GTFs or field tests, so it is critical to choose compatible scenarios. Also, it is important to consider the type of data that can be used for comparison and that it is compatible with data derived through hybrid GTFs or field testing.[19] Once validated, it is essential to periodically update or provide feedback to the model with actual test data so that it is kept current and remains valid.

Validation is seldom completed because it is an ongoing process of comparing qualitative and quantitative data from field testing, hybrid GTFs, or higher fidelity models. As a result, various levels or parts of validated models may exist. The level of validation will depend on the specific application,

amount of data required, accuracy, and confidence associated with the validation data.[20] It is also dependent on the level of detail required from the model, the validation process, the cost, and the required level of agreement between the model and results from hybrid GTFs or field testing. Since the validation process is ongoing and seldom completed, accreditation becomes the level of acceptable validation needed for a model when used for a specific purpose. This means that depending on the decision being supported, the level of validation required for some applications (e.g., pretest planning) may be at a lesser degree than for other such applications as performing the evaluation. Once the model has been developed, fielded, and activated, it must be maintained, updated, and validated at an acceptable level of performance throughout its life.

In addition, as the model gains acceptance as a valuable T&E tool, it is often modified to newer versions for use in other test programs. If these modifications to the model are not documented and controlled, the configuration may become unknown and the model's value as a T&E tool will be lost. As a result, the agency tasked to maintain the model must establish a procedure to control and document the configuration. Controlling the configuration of a model can be just setting up a procedure that ensures the model does not change without a formal process. When the configuration does change, the model will have to go through the VV&A process again to make sure the output is still acceptable. This can be as simple as running the model against a standard data set. The amount or size of the VV&A effort will depend on what was changed or modified and by how much.

Proper Mix of Test Tools

An important part of the electronic combat test process is the selection of the test and evaluation tools needed to answer the critical operational issues. There is a broad range of tools that can be used in the EC test process, each having its own particular purpose in supporting the test program. It is the test manager's responsibility to select from the box of T&E tools the ones that best support the test program and to ensure the tools are ready when testing is scheduled to begin. These T&E tools must be available and accredited at the start of each phase of the EC test process.

There are several possible ways of combining the test tools to address the COIs. The task is to decide the best mix between M/S, hybrid GTFs, and field test ranges. Some of the test constraints or factors that might be considered in developing the test approach and selecting the proper tools include the range of test issues, the funds allocated to testing, the time allotted for testing, and the level of confidence required in the results.[21] Making a decision is tough because the test manager has to commit to a test approach before some of the details of the test program are known. He may draw fire if one of the COIs cannot be answered adequately.

Test managers must recognize and understand the relative strengths and weaknesses of each tool for testing. Capt William Farmer and Col John Nagel developed table 2 with the objective of rating several test factors that affect the capability of each tool to effectively support OT&E of defense-suppression systems.[22] Although they only addressed defense-suppression systems, the ratings have the same impact across the spectrum of EC system testing when comparing the three major categories of EC test tools.

By examining table 2, one can see that a weak test factor for one tool may be complemented by the strengths of another tool. For example, the limited number of EC test systems for field testing can be overcome with the use of M/S and hybrid GTFs. However, the credibility of data will be much better with the actual EC system used in field testing than the data derived from M/S. The same argument can be made for the number and quality of the threat systems. A field test range is a very good place to evaluate the employment of tactics, but M/S and hybrid GTFs offer a better tool for developing tactics and employment concepts. In a hybrid GTF, you have operator interaction only with the closed-loop threat simulator; on a field test range not only do you have the interaction from the threat system operators but the friendly system operators can also be factors in the test scenario. However, as Farmer and Nagel point out, "there are sufficient limitations on the range so that even in the best test range environment all of the critical dynamic interactive

Table 2

Test Tool Strengths and Weaknesses

Test Factors	*Modeling & Simulation*	*Hybrid Ground Test Facilities*	*Field Test Ranges*
Identify Sensitivities	Very Good	Good	Fair
EC System			
Number	Very Good	Good	Fair
Creditability	Fair	Good	Very Good
Threat System			
Number	Very Good	Fair	Fair
Quality	Fair	Good	Very Good
Tactics			
Develop	Good	Very Good	Fair
Evaluate	Fair	Fair	Very Good
Configuration Flexibility	Good	Very Good	Fair
Environmental Realism	Fair	Fair	Good
Operator Interaction	N/A	Fair (Threat)	Good (Threat and Friendly)
Systems Interaction	N/A	Fair	Good

Source: Capt William D. Farmer and Col John F. Nagel, "Electronic Warfare System Operational Test and Evaluation," final report (Kirtland AFB, N.Mex.: Air Force Test and Evaluation Center, March 1980), 21. (Revised by author)

processes which occur between aggressor and defender are still not realized."[23] The important point that should be emphasized from table 2 is that a well-planned EC test process should use all the test tools to their full potential in evaluating an EC system.

A further comparison of the advantages and limitations between the three categories of test tools (table 3) was presented in a report on the *Test Process for Electronic Combat Systems Development*.[24] Table 3 is broken out into cost, capacity, timeliness, and credibility considerations for each EC test tool. Capacity has to do with the ability of the test tool to provide for force-on-force engagements with many hostile and friendly resources all taking part in the test scenario. The ability to easily change the threat baseline, as new intelligence on the threat system becomes available, is also considered a capacity of the test tool. Timeliness deals with time-sensitive issues in the acquisition of a system. Timeliness is a measure that determines how soon answers to key questions can be provided to decision makers. A test tool must also have the ability to support the evaluation and selection of one EC system over another when decision makers have to make prompt decisions to improve the survivability of a weapon system. Credibility has to do with believing that data from the various test tools is truly representative of the system under test. The data must provide the necessary confidence to influence the judgment of key decision makers.

In table 3, one can see that M/S and hybrid GTFs are less expensive to operate. They provide better capacity to evaluate many different force-level engagements in a timely fashion. However, the best source of credible data for the evaluation is field test ranges. Even though the field test range is expensive and field testing sometimes occurs too late to influence the acquisition decision, the data it produces is still very useful in the VV&A process and to fix systems that do not work right.

Table 3

Test Tool Advantages and Limitations

T&E Tools	*Cost*	*Capacity*	*Timeliness*	*Credibility*
Modeling and Simulation	Lowest	High	Hours/Days	Low
Hybrid Ground Test Facilities	Moderate	Moderate	Weeks/Months	Moderate
Field Test Ranges	Expensive	Limited Application	Months	High

Source: United States Air Force Ad Hoc Group, *Test Process for Electronic Combat Systems Development*, vol. 2, *Report and Appendices* (Andrews AFB, Washington, D.C.: AFSC/TE, 10 October 1988), 126. (Revised by author)

Ideally, the test manager will develop a test approach that incorporates a mix of T&E tools that generate as much credible test data as possible for the decision maker at the lowest cost. To do this, the test manager must go through a conceptual process of allocating funding against the generation of

quality test data.[25] This will help the test manager focus on designing a test program that will address the test issues with the appropriate test tool. After the test manager identifies the purpose and clearly spells out the requirements for each test tool, attention can then be focused on the cost of the approach and whether it answers the test issues to the satisfaction of the decision maker. Finally, it is important to involve the decision maker early in the test program so that the T&E tools needed to support his or her decision can be incorporated into the test approach.

By using a disciplined and structured EC test process, the test manager should be able to avoid drawing fire by being able to answer all the test objectives with the best mix of T&E tools. Chapter 3 provides a detailed description of the procedures for an orderly and structured EC test process.

Notes

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16. Quoted in Arnett, 2.
17. Ibid., 12.
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20. Modeling and Analysis Division, Headquarters Air Force Operational Test and Evaluation Center, "AFOTEC Modeling and Simulation Accreditation Process," draft document (Kirtland AFB, N.Mex.: Air Force Test and Evaluation Center [AFOTEC], 5 February 1992).

21. Mann, 62.

22. Capt William D. Farmer and Col John F. Nagel, "Electronic Warfare System Operational Test and Evaluation," final report (Kirtland AFB, N.Mex.: AFOTEC, March 1980), 19–21.

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24. Ad Hoc Group, vol. 2, 126.

25. Mann, 65.

Chapter 3

The Electronic Combat Test Process

After becoming familiar with the test and evaluation tools that are available, the test manager must next develop a test procedure to verify that the EC system can satisfy the user's mission need. The test procedure should encompass a structured approach that incorporates a standardized and disciplined test process. It should be designed in such a way as to provide an estimate of the system's effectiveness and suitability in an operational environment. Such a process will then satisfy the decision maker's need for timely and meaningful information in each phase of the acquisition process (see fig. 1).

This chapter describes a structured EC test process consisting of six distinct steps that can be applied to any EC test program. The foundation for this process is based on a scientific test methodology with the objective of conducting effective planning, test execution, and analysis of test data to measure the performance of the EC system. This process, depicted in figure 6, can apply to any stage of OT&E.

Scientific Test Methodology

The scientific test process allows for making a tentative assumption or a prediction of the system's performance (hypothesis). Then, through testing and analysis, a comparison is made between the actual performance results and the predicted hypothesis. The advantage of a scientific test process is that it provides structure and discipline to the test while verifying or refuting the hypothesis. In their paper "AF EC Test Process for RF Receivers," George F. McDougal, Michael J. Cooper, and Dennis J. Folds define six steps in a scientific test process. The six steps are (1) derive the operational test requirements, (2) complete pretest planning, (3) execute the test/assessment, (4) process the test data, (5) perform the posttest evaluation, and (6) report the results.[1] They also describe the methodology, the factors or issues that relate to the methodology, and the resulting products from each step in the T&E of radio frequency (RF) receiver systems (fig. 7). Although their paper centers around a test process for RF receivers, their fundamental scientific test methodology can be applied to any operational assessment or evaluation of EC systems. The remainder of this chapter describes each step in the scientific test process for EC systems.

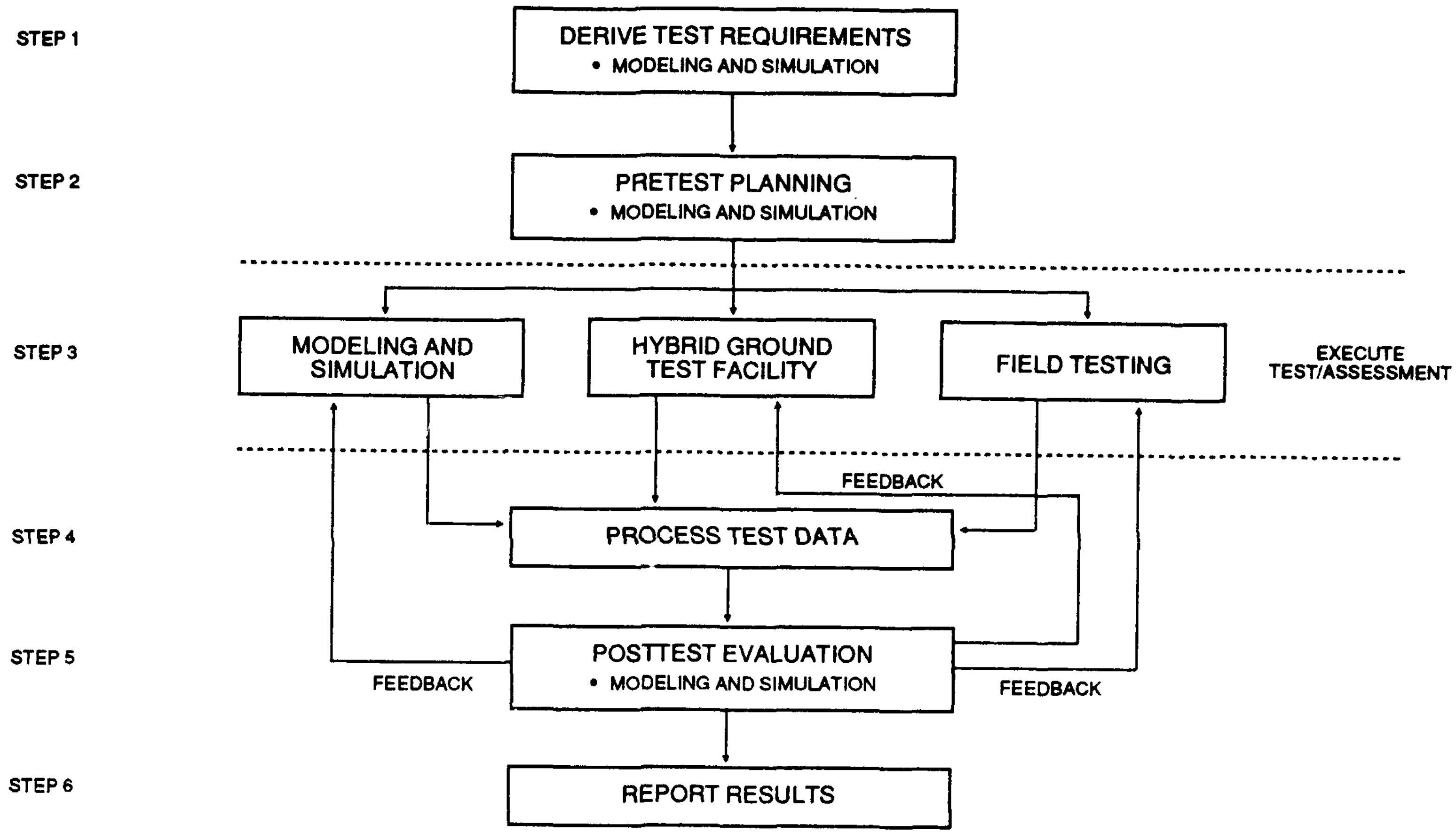


Figure 6. Electronic Combat Test Process

EC TEST PROCESS	METHODOLOGY	FACTORS/ISSUES	PRODUCTS
STEP 1: DERIVE OPERATIONAL TEST REQUIREMENTS	IDENTIFY QUESTION/PROBLEM	• OPERATIONAL REQUIREMENTS DOCUMENT • MISSION NEED STATEMENT • FUNCTIONAL REQUIREMENTS DOCUMENT • DEFICIENCY REPORTS • DETERMINE MEASURES OF EFFECTIVENESS (MOE) • DETERMINE MEASURES OF PERFORMANCE (MOP)	• CRITICAL OPERATIONAL ISSUES • TEST OBJECTIVES • TECHNICAL PERFORMANCE PARAMETERS • MOEs • MOPs • EVALUATION CRITERIA
STEP 2: COMPLETE PRETEST PLANNING	PLAN TEST	• TEST SCENARIOS/CONDITIONS • DATA REQUIREMENTS • TEST RESOURCE REQUIREMENTS • DATA PROCESSING AND ANALYSIS REQUIREMENTS	• TEST PLAN • INPUTS FOR TEST AND EVALUATION MASTER PLAN
	FORMULATE PREDICTIONS	• SYSTEM SPECIFICATIONS • PREVIOUS TEST RESULTS • TEST METHOD	• PERFORMANCE PREDICTIONS
STEP 3: EXECUTE TEST/ASSESSMENT	CONDUCT TEST	• TEST EXECUTION TASKS • QUALITY ASSURANCE	• "RAW" TEST DATA
STEP 4: PROCESS TEST DATA	ANALYZE RESULTS	• ALGORITHMS • STATISTICS	• TECHNICAL PERFORMANCE RESULTS • HISTORICAL RECORDS/DATA BASE • QUICK-LOOK REPORTS
STEP 5: PERFORM POSTTEST EVALUATION	COMPARE PREDICTIONS	• SYSTEM SPECIFICATIONS • COMPUTER MODEL PREDICTIONS • PREVIOUS TEST RESULTS	• ESTIMATE OF SYSTEM PERFORMANCE • VALIDATED PREDICTIONS • TEST TOOL CORRELATION • SUMMARY OF TEST RESULTS
	REFINE PREDICTIONS	• ACTUAL VERSUS PREDICTED PERFORMANCE • VALIDITY OF TEST RESULTS	• ADDITIONAL TESTS • EXTRAPOLATION OF TEST RESULTS TO OPERATIONAL ENVIRONMENTS
STEP 6: REPORT RESULTS			• FINAL TEST REPORTS

Source: George F. McDougal, Michael J. Cooper, and Dennis J. Folds, "AF EC Test Process for RF Receivers," *Proceedings of the IEEE 1991 National Aerospace and Electronics Conference*, vol. 3 (New York: Publishing Services, IEEE), 1340 (revised).

Figure 7. The Scientific Test Method

Deriving the Operational Test Requirements

The first step in the EC test process is to derive the operational test requirements. Operational test requirements are developed from the user's mission need or stated operational requirements. Deriving operational test requirements is extremely important because it identifies the questions or critical operational issues that need to be answered and will ultimately result in the development of the test objectives. COIs are key operational effectiveness or suitability questions that must be examined to determine if the system is capable of performing its mission. Test objectives break down the COIs into clearly defined, manageable tasks or areas to be examined, and they form the basis of an effective test plan. They originate from operational requirements that are defined by the MAJCOMs and stated in the mission need statement (MNS). Even though there will be cost, schedule, and performance trade-offs, the test objectives will remain the same at successive milestone decision points and not increase in number. After the objectives have been identified, a method must be devised to evaluate or assess whether the system can satisfy each objective.

Deriving the test requirements begins by gathering together the program documents that describe the mission, the deficiencies in the current capabilities, and the proposed system concept. This information can be obtained from such sources as the PMD, MNS, or the operational requirements document (ORD).

Once a detailed description of the operational mission and the proposed system concept is provided, a mission-level computer simulation of the proposed operational scenario can be used to further refine and identify the EC system's mission-level requirements. Again, the MAJCOM is responsible for developing the mission-level requirements and will most likely develop the mission-level simulation for the analysis. Developing a computer simulation of the operational scenario is not a requirement for the OTA. But if available, it can be quite useful in determining the critical operational issues that the proposed system concept is designed to fill in the stated mission need. With a mission-level computer simulation, analysis of postulated combat scenarios will lead to an initial list of system capabilities required to perform the mission. From this list test objectives, along with quantitative and qualitative measures, can be developed. Eventually, evaluation criteria and data requirements for the evaluation can be determined.[2]

Measures are used to answer the objective and help to further refine the test planning process. They also provide a link between the test objective and the specific test method used to evaluate the EC system. A measure provides a quantitative basis for comparing a system's performance to a specified requirement. However, there are two types of measures that need to be developed to determine if the system is effective in meeting the mission need. The first is a mission-level measure of effectiveness (MOE) that determines the overall degree of mission accomplishment. MOEs judge the operational

effectiveness and suitability of the system under combat-like conditions. However, in most cases they cannot be directly addressed through field testing.

The second type of measure is the measure of performance (MOP), which provides a basis to determine how well system-level performance requirements are being met. MOPs are lower-level measures that directly relate to the MOEs. A change in the system-level measure, such as threat-detection range, electronic countermeasure technique assignment, or threat location accuracy, should have an effect on the mission-level MOE. Unlike test objectives, measures will become progressively more specific and increase in number at successive milestone decision points. The OTA will develop the operational MOEs and MOPs as the objectives for evaluating the EC system become clear.

MOEs are also used in the cost and operational effectiveness analysis (COEA) process to show how alternative solutions compare in meeting mission needs and to discriminate between the alternatives. Generally, each alternative is evaluated against existing capabilities with MOEs that are suitable for comparison. It is the MAJCOM's responsibility to develop key MOEs to be used in the COEA process. However, because of the OTA's expertise in developing MOEs, the OTA can support the MAJCOM by helping establish appropriate COEA MOEs. COEA MOEs translate measured or predicted levels of performance for each alternative into statements of relative effectiveness. This information is used to verify that the level of performance assumed in the COEA has been achieved in the actual system.[3] If the level of performance for the selected alternative is not achieved, then testers must assess and document how the reduced performance will impact on the system's mission effectiveness.

DOD Instruction (DODI) 5000.2, *Defense Acquisition Management Policies and Procedures*, states that to perform this assessment, the "measures of effectiveness should be developed to a level of specificity such that a system's effectiveness during developmental and operational testing can be assessed with the same effectiveness criteria as used in the COEA."[4] However, to use the same evaluation criteria, there must be a direct correlation between the MOEs used to evaluate the operational effectiveness and suitability objectives and those used to determine the best alternative. Where there cannot be any direct measurement to support the MOEs, MOPs must be derived that relate system-level results to the MOEs and to the COEA.

Here again, a computer simulation that incorporates an EC digital system model and a definition of the proposed mission scenario can assist in identifying mission-level MOEs and performance requirements in terms of MOPs. Modeling and simulations can also help establish the quantitative relationships between the measures of effectiveness and the measures of performance. In the COEA process, models are used to estimate how a particular alternative would perform in accomplishing the mission objectives. The COEA modeling effort is the responsibility of the MAJCOM. If this model is

made available to the operational test agency, then it can be used to help determine the operational measures.

Associated with the test measures are evaluation criteria. They are the standards used to judge the achievement of operational effectiveness and suitability requirements. Evaluation criteria consist of specified value ranges for each performance characteristic in which the measured values must fall to meet the MOEs/MOPs. They are tied directly to the MAJCOM's stated operational requirements and can be derived through analysis of a range of values that impact the performance of the system. DOD policy requires that meaningful COIs, test objectives, MOEs/MOPs, and mission-related evaluation criteria be established before testing begins. This is essential because criteria facilitate the development of methodology to evaluate and assess the EC system's ability to meet operational requirements. Also, the data requirements and the T&E tools used to generate the data can be identified by establishing the evaluation criteria. The criteria associated with the COEA are expressed in the form of cost and performance thresholds and must be clearly identified and explained prior to the start of the evaluation or assessment. Although the OTA develops the test requirements and measures, the responsibility for developing the evaluation criteria for all measures rests with the user.

It is important to point out that using system development contractors to establish test requirements for operational testing beyond the low-rate initial production (LRIP) decision is restricted by Title 10, *United States Code*, section 2399, "Operational Test and Evaluation of Defense Acquisition Programs." Title 10 states that

> a contractor that has participated in (or is participating in) the development, production, or testing of a system for a military department or Defense Agency (or for another contractor of the Department of Defense) may not be involved (in any way) in the establishment of criteria for data collection, performance assessment, or evaluation activities for the operational test and evaluation.[5]

This means the test manager must be careful when using contractor-developed models to support the development of test requirements for IOT&E and beyond. The test manager must monitor the development of the models to see that they are fair and that they have been verified, validated, and accredited. When it is time to run the models, the test manager must ensure that the contractor is not involved with conducting or assisting in the operation of the model, or even acting as an advisor.

Completing the Pretest Planning

As figure 7 shows, pretest planning entails a process of planning a test that encompasses the key factors to the test plan and making performance predictions. Pretest planning consists of analyzing test constraints, applying the principles of scientific test design, and specifying the test procedures.[6] The

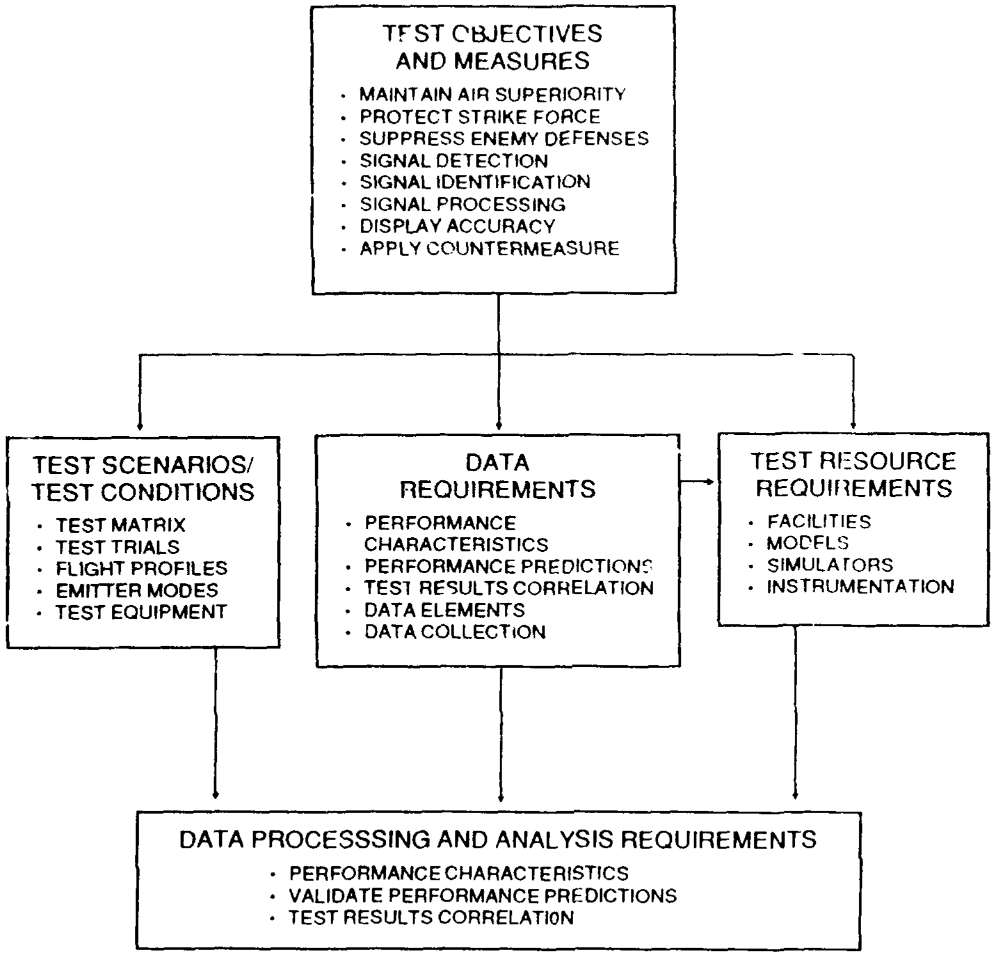
tester, by transforming the detailed *test requirements into test procedures*, can develop a test approach or plan. During pretest planning the testers will make sure the measurable performance values for each MOE or MOP are clearly spelled out and that they predict EC system performance for comparison against actual test results. When designing the test, sufficient test points should be planned to support the comparison of test results to the pretest predictions, the calibration of the test tools, and the correlation between the test tools.

Each of the key factors to the test plan are dependent on and developed from the derived test objectives. Figure 8 depicts the key factors that make up the test plan and their relationship to one another. They include operational test scenarios and test conditions, data requirements, test resource requirements, and data-processing and analysis requirements.

The task of setting up the test scenario and selecting the test conditions requires information on the operational environment and the threats that have the most impact on successfully accomplishing the mission. Part of this information is provided by documents that state the mission and the operational scenario. However, it is the intelligence community that provides intelligence estimates of the representative threat environment. During pretest planning, the Air Force Intelligence Command (AFIC) and the OTA's own intelligence division are tasked to provide the technical data on the threats—defining the operational threat environment and validating the test scenarios.[7] They will also supply threat information to the appropriate agencies for validating the models and threat simulators. Intelligence on the *threat environment* will then drive the development of the operational test scenarios used in the hybrid GTFs as well as the field test ranges. The testers tailor the intelligence support to the specific test program to determine the optimum operating modes of the threat, its scan pattern, and the operating frequencies for use in assembling the electromagnetic test environment to satisfy the test objectives.

If the test environment needs to be realigned to match the representative combat environment, M/S with the latest intelligence estimates can be used to identify the layout of the threat simulators for either the hybrid GTF or field test range. Analysis of the simulation can help optimize flight path options for friendly and hostile aircraft in the scenario. And through computer simulation, testers can select the sequence for the test trials that best satisfy the test objectives.

A report published by BDM International titled "ASPJ Test Requirements and Test Concept Developed through Analysis and Simulation," provides a good example of using the computer simulation, the suppression model, as a tool to develop an operational scenario and a set of test conditions for the airborne self-protection jammer. This scenario included the location, number, and types of threat simulators on the range and a script identifying the specific periods when the threat simulators would engage the aircraft. Al-



Source: George F. McDougal, Michael J. Cooper, and Dennis J. Folds, "AF EC Test Process for RF Receivers," *Proceedings of the IEEE 1991 National Aerospace and Electronics Conference*, vol. 3 (New York: Publishing Services, IEEE), 1342 (revised).

Figure 8. Key Factors of Test Plans

though total realism cannot be obtained on the test range, the computer simulation did determine the most realistic operational test environment possible given the limited test resources. Additionally, the simulation determined

- the impact of EC support assets on the mission,
- the conditions under which ASPJ would be required to perform,
- the specific threats that would engage the aircraft and when,
- the engagement geometries, and
- the outcome of the engagement.[8]

Once the test scenario is identified, the next step is to perform an analysis of the scenario and test conditions to derive the data requirements. Data requirements are dependent on the MOEs or MOPs and must be identified early in the development of the test plan. As depicted in figure 8, the data requirements will also have some effect on the selection of test resource requirements. The analyst tasked to perform the analysis is the one who develops the detailed test procedures that provide a description and definition of each data element to be collected. Data elements support the analysis of specific performance requirements that are associated with each measure. Data is also needed to monitor compliance with the test procedures and to make sure safety considerations are adequate.

Other applications for data include quality control of the data to make certain the test results remain valid, to predict the performance of the system and refine the analysis tools, and to support the correlation of test results with other test tools.[9] Data is also required to document the test environment, to identify any anomalies in the expected results, to repeat the test event when duplicating a problem, or to analyze the test environment when looking for test assumptions that may be different or that may have been violated.

The analyst also selects the required output data products such as printouts, plots, or magnetic tapes that will have an effect on the data-processing requirements. The tendency to collect large amounts of data must be balanced with adequate plans for data processing and analysis. In their paper "Data Acquisition, Processing, and Analysis for Electronic Combat," Dr David Culp and Arthur Smail state that

> when a large number of data variables are defined in a requirement, vast quantities of data are inevitably collected. This causes a significantly increased work load for data acquisition, data analysis, and data processing. The time required to test, analyze, validate, and document each additional data parameter is significantly increased.[10]

A method to overcome the collection of large amounts of data is to completely define and specify the data elements.[11] Data elements should be based on the test requirements and influenced by the analysis procedures. This will in turn help define the test design and develop the data-collection system.

The data-collection system must provide the analyst with enough data to assess the test results. Yet it is important that the data-collection system be designed to minimize its impact on the performance of the EC system. The data-collection system must also interact with the test resources in a manner that does not interfere with the operational realism of the test and the quality of the data.

Test resources (see fig. 8) are assets that support the T&E of the EC system. They include the test facilities, models, threat simulators, friendly support assets, instrumentation systems, range tracking systems, mission control centers, test facilities, environment generators, and so forth. The requirement for a specific test resource is driven by the data requirements that are used to support the MOEs or MOPs. Depending on which test resources are

used in the EC test process, they can be used to support the development of performance predictions, provide data for the correlation between the T&E tools, and determine the quality of the test data that is generated.

The analyst is tasked to define the test resource requirements needed to support the objectives. Such detail as threat simulator and environment generator requirements, instrumentation requirements for the hybrid GTF or field test range, and mission-support assets (e.g., cables, power supplies, cooling systems, and test equipment for hybrid GTFs; and bombs, missiles, other aircraft, and instrumentation pods for field testing) must be identified. Stating the resource requirements early in a test program allows for the identification of shortfalls that can be incorporated into improvement programs so the test resources will be ready at the start of the test.

There are several different types of instrumentation systems that need to be considered during pretest planning. The first provides information as a function of time during the test mission. For example, on the field test range, an aircraft's position within the test environment is provided by time-space-position information (TSPI). The requirement for TSPI is to provide location information on individual aircraft operating over a large area at all altitudes. It must also provide precision information when determining threat system-tracking errors or missile-miss distances.[12] In a hybrid GTF, TSPI is not a problem because the aircraft's flight path is an input value to the simulation.

Another example of an instrumentation resource that is essential to the test is the spectrum-monitoring system. This system can monitor and record the operating frequencies of all ground and airborne emitters participating in the test as well as the field test environment. Being able to monitor the performance and status of each emitter in the scenario during the test gives the test director a way to identify the emitters that are not radiating or operating as planned. Also, at the conclusion of the test, an analysis can be performed on the RF background to assess any stray signals not associated with or interfering with the test.

The capability to monitor and record switch actions is another element of the instrumentation system. To reconstruct the test mission and understand why certain events occurred, the actions of each participant must be recorded. This should shed light on the manner in which the test resources were operated and why the test outcome occurred as it did.

The instrumentation resources listed here are not all inclusive, but are only examples. The data requirements will determine just exactly what kind of instrumentation resources are required for the hybrid GTFs or field test ranges.

The final key factor that must be taken into account during the development of the test plan is the data-processing and analysis requirements (see fig. 8). The data-processing and analysis requirements are derived from the methodology used to answer the operational measures. The analyst is the one tasked to develop a data-processing and analysis strategy that will address each performance characteristic of the system. Test conditions, resources, performance predictions, the calibration of the test tools, and the correlation

of the results have an effect on the data-processing and analysis requirements. This section of the plan should provide an explanation of how the data will be collected and what will be done to the data to transform it into a form for analysis. Once the data is reduced and processed, the plan must show how the analysis of the test results are conducted to address each measure. Usually this amount of detail is incorporated into a separate document called the data management and analysis plan (DMAP) or placed in an annex to the test plan.

It is extremely important to develop and test the data-processing and analysis routines prior to the start of testing. However, in practice, this is not easy to do because of last-minute changes to the EC system or the data requirements. This can force new demands on or changes to the data-collection system or to the processing and analysis routines. To accommodate these types of changes, the software used to process and analyze the data must be flexible enough to make changes quickly and easily, because once the test has started much of the time will be taken in conducting the test, leaving little time to finish developing the data-processing and analysis routines.

An important part of pretest planning that is often omitted is the generation of performance predictions.[13] Performance predictions will help the test manager determine the test conditions that are critical to the evaluation of the system and predict the system's performance to selected objectives. These predictions can assist in making effective use of the limited test resources by allowing the test manager a chance to survey the test matrix. This in turn provides the opportunity to optimize the test conditions with the limited test resources and to develop a set of pertinent operational test conditions for each objective. Performance predictions are also used to compare against measured test results when correlating the results between the test tools and validating the models or the hybrid GTF's threat simulators.

Mission-level computer simulations of the operational environment can be used during pretest planning to help determine which test conditions and data requirements are needed to satisfy the test objectives. Another excellent application for a computer simulation in pretest planning can be to assist in

- designing the test scenario,
- setting up the test environment,
- identifying the proper instrumentation requirements,
- determining the manning and control of the test resources,
- selecting the best sequence for the test trials, and
- predicting outcome values that can be used to compare with the actual test results.[14]

When designing and setting up the test scenarios, a mission-level computer simulation can examine the proposed operational mission scenarios. The same mission-level computer simulation can be used to identify the threats of interest that will make up the test environment. In most cases, this mission-level simulation will be the same one developed by the MAJCOM and used to

prepare the COEA. With this information and the limited test resources at the hybrid GTFs or field test ranges, a representative test environment can be developed that replicates to the best of our ability the combat environment.

With the help of an EC digital system model, modeling and simulation can be used to predict the expected performance of the actual EC system in the combat environment. These predicted responses can then be used to compare with the actual EC system's capabilities to detect, identify, and process threat signals and mode changes in the test environment. Given that the performance predictions have been accepted with reasonable confidence when accredited and correlated with actual test results, the test director can then extrapolate the system's performance to operations that cannot be performed in the field test environment. Also, the results from the EC digital system model can be fed into a system-level model of the threat system to predict the EC system's effectiveness in degrading the performance of the threat system and then comparing those results to actual test results. Once the test plan has been developed and approved, the next step is to execute the test or assessment.

Executing the Test or Assessment

The third step in the scientific test process consists of executing a sequence of test trials and tasks designed to assure the collection of quality data for a posttest evaluation (see fig. 7). The test-execution tasks consist of instructing test team and operator personnel on their responsibilities, calibrating all applicable test resources and instrumentation systems prior to the start of the test trial(s), ensuring the collection of valid test data after the test has started, and calibrating the test resources at the end of the test.[15] These tasks make up a process of controlling the quality of the test results. They ensure that the test results will not be corrupted by uncontrollable factors, variations in measurements, and erroneous data. As the test is being executed, the test director is responsible for monitoring the test and guaranteeing the collection of quality data. These quality control tasks apply to both the hybrid GTFs and field test ranges, although they may have to be tailored to the specific capabilities and resources in the hybrid GTFs or the field test ranges.

Instructing the Test Team

Before the test starts, the director must ensure that all personnel involved understand the overall test program and their responsibilities in executing the test. McDougal, Cooper, and Folds suggest that "these instructions should include the scope of the test plan, specific test objectives, descriptions of the test items, and methods for conducting each test."[16] These instructions should also include a description of all signal parameters that the EC system will be sensing in the test environment, the operating modes for the EC

system, the host aircraft's operational configuration, and the flight test profile. In addition, the test director must give the facility or range instrumentation system operators the specific test conditions and sequence of measurements that need to be collected.

Pretest Calibration

On the day of the test, the director has to make sure the test resources and instrumentation systems are calibrated and functioning. Additionally, the EC system under test should be checked to make sure that all modes of operation are functioning properly and that the system will respond to the test environment. Signal characteristics from each test resource should be calibrated to the operating parameters specified in the test plan and verified to be operating properly. Any significant pretest calibration results that show a deviation from what is expected must be reported and documented by the test team.

If the calibration is off to the point where the test result will be invalid, the test director should postpone the test until the problems can be fixed or fly a backup mission that is not affected by the problem.[17] Canceling the test is also an option, but range time is too expensive and hard to come by to cancel, so the test director should always have a backup plan.

Monitoring the Test

Once the test has started, the director must monitor the execution of the test to ensure it is proceeding as planned and verify that sources of error are kept to a minimum. Without usable or reliable data, there is no test. Methods the test director can use to confirm the collection of usable test data include near-real-time monitoring of the test environment and checking on the quality of data from the EC system. The test director can also compare selected test results to the predicted values generated during pretest planning.[18]

Near-real-time monitoring of the test and data is essential if the test director is to maintain control over the test. Near-real-time monitoring gives the test director the opportunity to ensure that the test aircraft are flying along their planned flight paths, that the test resources are functioning properly, and that instrumentation systems are working and producing quality data. If it is determined that the test is not producing usable data or not going as planned, the problem can be fixed or a work around determined, or the test can be terminated without further expenditure of costly resources.

Using quick-look data at the end of each mission is another way of allowing the test director the opportunity to assess the value of the test data and progress prior to the next scheduled mission. This cursory look at the data reduction and analysis products may highlight some unforeseen problem in the data and make it worthwhile to repeat the mission before the test has ended. Performing a quick-look analysis also allows the test director the opportunity to make certain that the planned data processing and analysis

routines will work and that the output products are what is needed to evaluate the EC system.

Signal characteristics from the test resources in the field test environment should be monitored and recorded during the test to verify the correct signal environment. It is also important to perform a spectral analysis of the test environment to record any unwanted or unintended signal emissions that might impact the test results. Flight test profiles must be monitored and recorded to ensure range safety and to reconstruct the mission profile for posttest analysis. These concerns are not a problem when using M/S or hybrid GTFs because these tools offer very controlled environments. Finally, the EC system must be monitored and its output recorded for comparison with the signal environment and pretest performance predictions.[19]

Posttest Calibration

At the completion of the test, a posttest calibration of the test resources and the instrumentation systems is performed to ensure they are operating properly. The calibrated data can then be compared with pretest calibration results to see if anything has changed significantly and whether it would impact the test results. If there are significant differences between the pre- and posttest calibration values, the test may have to be reaccomplished.

Processing the Test Data

Once the "raw" data has been collected, the next step is to process it. All data (e.g., TSPI, emitter characteristics, spectrum analysis, operator logs, and data from the EC system) that was measured and collected must go through a data-reduction process, where it is assembled in a form favorable to performing analysis and comparison to performance predictions or to previous test results. Through analysis of the data, the EC system's level of performance can be quantified with respect to each measure. Initially, the analyst closely examines the data to make sure that it is complete and that the results are consistent throughout the test trial. After the analyst determines that the data is complete and consistent, he or she then formats and time-correlates the data so that it can be processed by mathematical operations in the data-processing and analysis routines. Since OT&E involves an event-oriented analysis, the analyst must be on the lookout for timing problems with the instrumentation system such as the accuracy of the timed events, or that all data sources are set to the same reference time.

With the help of computer processing to run both the data-processing and analysis routines, processing of large amounts of test data can be sped up. But even though computers can speed up the processing of the data, they can still take days, weeks, or months to complete the job. The time to process the data will depend on the following factors:

- Is the data-reduction equipment at the same location where the test is being conducted?
- Does the raw data have to be shipped to some other location for processing?
- Are the data-reduction and processing routines complete and functioning properly?
- Is the data scattered over a wide geographic area?
- Are there enough personnel to process and analyze the results in a timely manner?

Each factor will have some impact on the time it takes to get the results and will have to be considered when determining the time needed to process the test data.

Depending on which stage of OT&E the program is in and the T&E tool being used, the processed data can assist in selecting performance criteria for further testing, facilitate the planning of any subsequent test, or correlate test results between various test tools.[20] Furthermore, the results from the processing step can be used as a source of quick-look data to assure the collection of quality data. As soon as the test data is processed, a posttest evaluation of the EC system's performance can begin.

Performing the Posttest Evaluation

The fifth step in the scientific test process is to perform the posttest evaluation. It is composed of analyzing the EC system's performance, comparing test results to pretest predictions, extrapolating the test results to other operational scenarios, correlating the results between the test tools, and summarizing the processed data collected from the test trial(s) (see fig. 7).[21] Test results representing system-level performance are compared with the evaluation criteria to determine if the system met or did not meet the MOP. In addition, the test results are compared against predicted performance results generated during pretest planning. The reason for comparing the test results with the model predictions is for validating or accrediting the model for use in estimating mission-level outcomes or measures.

If there are any differences between the predicted and measured values, a determination must be made as to whether there is a lack of fidelity in the test resources or computer simulations, defects in the test design, or problems in the performance of the EC system.[22] When the test resources or computer simulations lack the needed fidelity, they must be updated to reflect the correct performance of the threat system, based on current intelligence estimates, and the test trials repeated as necessary. When the source of the differences is the test design, the test may have to be restructured and rerun.

Throughout the EC test process, the extrapolation of performance predictions to operational scenarios is ultimately contingent upon comparing, validating, and accrediting the pretest M/S predictions with field testing (fig.

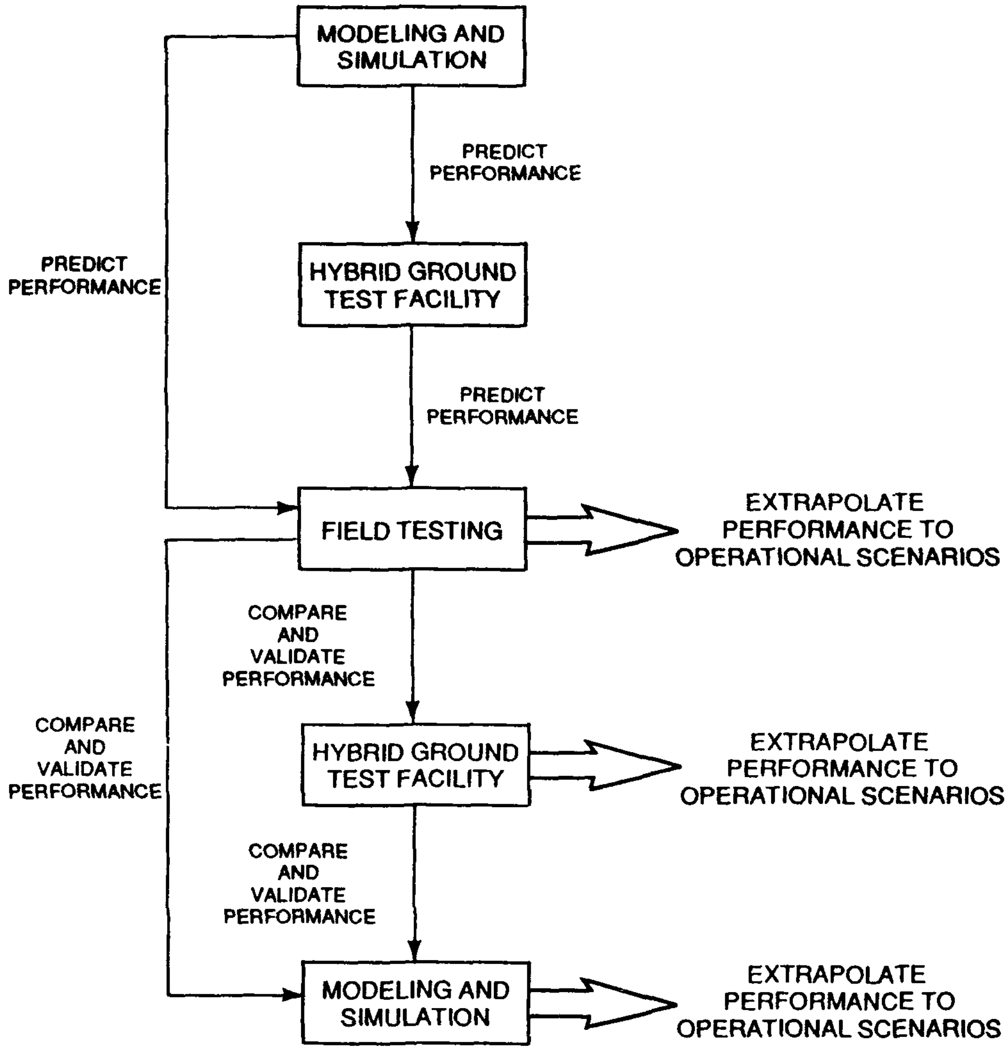
9). Validation and accreditation of performance predictions are essential when extrapolating test results to operational scenarios that cannot be evaluated in the test environment. Predicted and measured values should match well enough to provide high confidence in the EC system model. During the posttest evaluation, any VV&A that takes place must be documented in order to confirm the degree of validity of the model results.

Even when range results match fairly well with the pretest predictions, comparing test results obtained from the different test tools and supplying the proper feedback to calibrate the test tools provide credibility to the EC test process. A disciplined test process will compare the test results obtained in the hybrid GTF with those obtained from computer simulations. By the same token, field test results should be compared with the test results obtained from both the hybrid GTF and computer simulations (see fig. 9). Calibrating the performance predictions with the measured test results during each stage of the test process will improve the accuracy of future performance predictions.

It is during the posttest evaluation that the correlation is made of the test results obtained from using each of the test tools under similar test conditions. The degree of correlation obtained between the test tools will influence the validity of the test results. Once the test results have been correlated with the T&E tools, and the pretest performance predictions have been validated and accredited, the test director can then use the M/S tools to generate updated performance predictions for any subsequent testing. The test director can also answer the mission-level MOEs by using the models to extrapolate the EC system's performance to the operational scenario.

In most cases, the system-level measures can be answered through direct application of the processed field test results. However, the primary purpose of the OT&E is to measure the system's contribution to mission accomplishment rather than just determining system performance. Because of the requirement to estimate the EC system's contribution to the mission, there will be cases where mission-level MOEs cannot be determined through direct application of field test results. This is due to the fact that certain test conditions cannot be replicated in the field test environment. Limitations such as shortages of test resources, a less-than-representative test environment, or an EC system that is still evolving will have a bearing on reproducing a realistic operational test scenario to answer mission-level MOEs. Therefore, to be able to answer the mission-level MOEs, the analyst may have to return to the same computer simulation that was used in designing the test to determine the EC system's effectiveness in its intended operational environment. Feedback of field test results to calibrate and accredit the models is essential for this effort to succeed.

The analyst, by producing field testing results that validate and accredit the performance predictions at a system level of detail, can extrapolate the EC system's performance in a representative operational scenario using mission-level simulations. Of course when using models to extrapolate performance of the system, it will be at the cost of increasing "risk" to the evaluation. Risk



Source: George F. McDougal, Michael J. Cooper, and Dennis J. Folds, "AF EC Test Process for RF Receivers," *Proceedings of the IEEE 1991 National Aerospace and Electronics Conference*, vol. 3 (New York: Publishing Services, IEEE), 1345 (revised).

Figure 9. Extrapolating Test Results to Operational Scenarios

comes from the fact that there will always be some uncertainty that the models will give a true picture of the system's capabilities. This is going to always be true even if the models or simulations have gone through the VV&A process.

It is also during posttest analysis that the MAJCOM will review and update the COEA to determine whether the selected alternative is still the most

cost-effective approach in satisfying the operational requirement. This is done by comparing measured test results to those predicted for the COEA measures of effectiveness and performing a sensitivity analysis to determine whether the EC system is still the optimum alternative. The OTA can assist the MAJCOM in the COEA process by providing operational test results for the MAJCOM analysis.

Posttest evaluation for each acquisition phase is complete when the values for each measure are determined, the differences between the predicted results and actual results are resolved, and the test results are documented and recorded along with the processed test data. The test results can support other studies, EC test programs, and the decision makers when they have been documented and recorded. If further testing is required, results from the posttest evaluation should be fed back to update the test tools and to reaccomplish pretest planning for current or follow-on phases of the EC test program.

Reporting the Results

The final step in the scientific test process is to report the results to key decision makers in the acquisition process, to their staffs, and to the MAJCOM so they can be acted upon. The report should be organized in such a way as to get needed information into the proper hands on time. The final report must be organized and based on what type of information is needed, when, and for what purpose. The final report should provide an executive summary up front that summarizes the results in enough detail to support an acquisition decision. The remainder of the final report provides a permanent record and audit trail of significant OT&E data, limitations, results, conclusions, and recommendations. The final report should be written objectively and relate the test results to user requirements. In a 1986 report to the Senate Committee on Governmental Affairs entitled *Weapon Performance: Operational Test and Evaluation Can Contribute More to Decisionmaking*, the General Accounting Office recommends that the final report

> 1) state whether OT&E demonstrated that the system met operational requirements, 2) discuss the operational effect of significant test limitations and adverse test results on system performance, and 3) clearly state whether the system tested is operationally effective and suitable.[23]

The final OT&E report must be approved and signed no later than 60 days after the last test event as required by AFR 55-43, *Management of Operational Test and Evaluation*.[24] If the final report is not ready for release 45 days before the scheduled milestone decision, an interim summary report is authorized.[25] However, unless the posttest evaluation is complete, an interim summary report should not be used to support an acquisition decision. In most cases, an interim report is based on interim results instead of a complete analysis of the test results to include the necessary feedback to the models.

Therefore, it should be used only in those cases when the analysis is complete and the final report cannot be published in time for distribution. The interim summary report is usually in the form of a message that summarizes the OT&E findings in enough detail to support the decision makers. The technical information generated during the test and used to support the conclusions should be documented in separate data documents.

A formal briefing may be used in support of, or in some cases, instead of, the final report. The briefing may be presented as an executive-level presentation to key decision makers and other interested agencies (i.e., operating, supporting, and participating commands).

This concludes the description of a structured scientific test process for the evaluation of EC systems. It is a process that can be tailored to the specific EC test program and applied to any stage of OT&E. Depending on the status of the test program and the acquisition phase, portions of the scientific test process may not need to be reaccomplished. For example, deriving MOEs may not be necessary as the program enters into the engineering and manufacturing development phase because the MOEs should have been determined during the previous phase. Of course there are always exceptions, and a review of what has been accomplished as well as an understanding of the objective for the particular stage of OT&E will give the test manager an indication of the appropriate steps that need to be accomplished in the EC test process.

It must be understood that by following a disciplined test process, OTAs must plan for sufficient time and money at the conclusion of the test to feed the data back into the models and hybrid GTFs. It also means that the OTA cannot use the money programmed for providing feedback to the models and extrapolating test results for extra flight tests when there is a problem to resolve and a milestone decision point coming up. A disciplined test process also provides the shortest method to acquire quality systems. But if shortcuts are taken or part of the process is left out to save time or money, the test process invariably will take more time. By sticking with a disciplined test process, the OTAs will be able to standardize the OT&E of EC systems.

Now that a basic description of the T&E tools and the steps to the scientific test process have been presented, it is time to see where the tools are used to support each phase of the acquisition process. Chapter 4 describes the tasks to be accomplished by the system program office and operational test agencies when applying the T&E tools in a scientific test process to support EC system program decisions.

Notes

1. George F. McDougal, Michael J. Cooper, and Dennis J. Folds, "AF EC Test Process for RF Receivers," *Proceedings of the IEEE 1991 National Aerospace and Electronics Conference*, vol. 3 (New York: Publishing Services, IEEE, 20–24 May 1991), 1340.

2. Help in determining the COIs, test objectives, measures, and data requirements can come from experienced analysts within the test agency, from handbooks, or from training courses such as the OT&E course taught at Headquarters AFOTEC.

3. Memorandum, ASD/PA&E, subject: Incorporating Cost and Operational Effectiveness Analysis (COEA) Measures of Effectiveness (MOE) into Test and Evaluation, Draft Implementation Guidelines (Revised), undated.

4. DOD Instruction (DODI) 5000.2, *Defense Acquisition Management Policies and Procedures*, 23 February 1991, 4-E-4.

5. *United States Code* Annotated, Title 10: *Armed Forces*, 1992 supplementary pamphlet, sec. 2399 (Saint Paul, Minn.: West Publishing Co., 1992), 405–6.

6. McDougal, Cooper, and Folds, 1342.

7. Col John Clark, Air Force Intelligence Agency (AFIA), Kirtland AFB, N.Mex., interview with author, 11 February 1992.

8. R. H. Lewis and P. R. Landweer, "ASPJ Test Requirements and Test Concept Developed through Analysis and Simulation (U)," BDM/A-1227-90-S, Research report prepared for Air Force Operational Test and Evaluation Center, Kirtland AFB, N.Mex. (Albuquerque, N.Mex.: BDM International, 30 March 1990), abstract. (Secret) Information extracted is unclassified.

9. McDougal, Cooper, and Folds, 1343.

10. David B. Culp and Arthur W. Smail, "Data Acquisition, Processing, and Analysis for Electronic Combat" (Paper presented at the 1982 Air University Airpower Symposium, Air War College, Maxwell AFB, Ala., 1–3 March 1982), 26.

11. Ibid., 27.

12. The types of TSPI systems generally fall into the two categories of area and precision coverage. Area coverage provides information on the location of large numbers of players anywhere within the test environment. At initial detection ranges, area TSPI provides good coverage of all the aircraft on the test range, but it cannot provide the precise location of the aircraft needed for some of the test objectives. Precision TSPI can provide the precise location of the aircraft in relation to the threat system when measuring threat system-tracking errors. Precision TSPI can also be used as inputs to missile flyout models to estimate simulated missile-miss distances. However, when using a radar to provide precision TSPI, the detection range and the number of aircraft it can track at one time is limited. But by deriving TSPI from other sources such as GPS or high-speed film, or by using triangulation between several sources, these limitations can be overcome and precise tracking information can be provided.

13. McDougal, Cooper, and Folds, 1342.

14. Michael R. Deis, "The Air Force Electronic Combat Test Process," *Proceedings of the IEEE 1991 National Aerospace and Electronics Conference*, vol. 3 (New York: Publishing Services, IEEE, 20–24 May 1991), 969.

15. McDougal, Cooper, and Folds, 1344.

16. Ibid.

17. Ibid.

18. Ibid.

19. Ibid.

20. Ibid.

21. *Air Force Electronic Combat Development Test Process Guide* (Washington, D.C.: Department of the Air Force, 1 May 1991), 33.

22. Ibid., 16.

23. Senate Committee on Governmental Affairs, *Weapon Performance: Operational Test and Evaluation Can Contribute More to Decisionmaking*, GAO/NSIAD-87-57 (Washington, D.C.: General Accounting Office, December 1986), 4.

24. AFR 55-43, *Management of Operational Test and Evaluation*, 29 June 1990, 44.

25. Ibid., 43.

Chapter 4

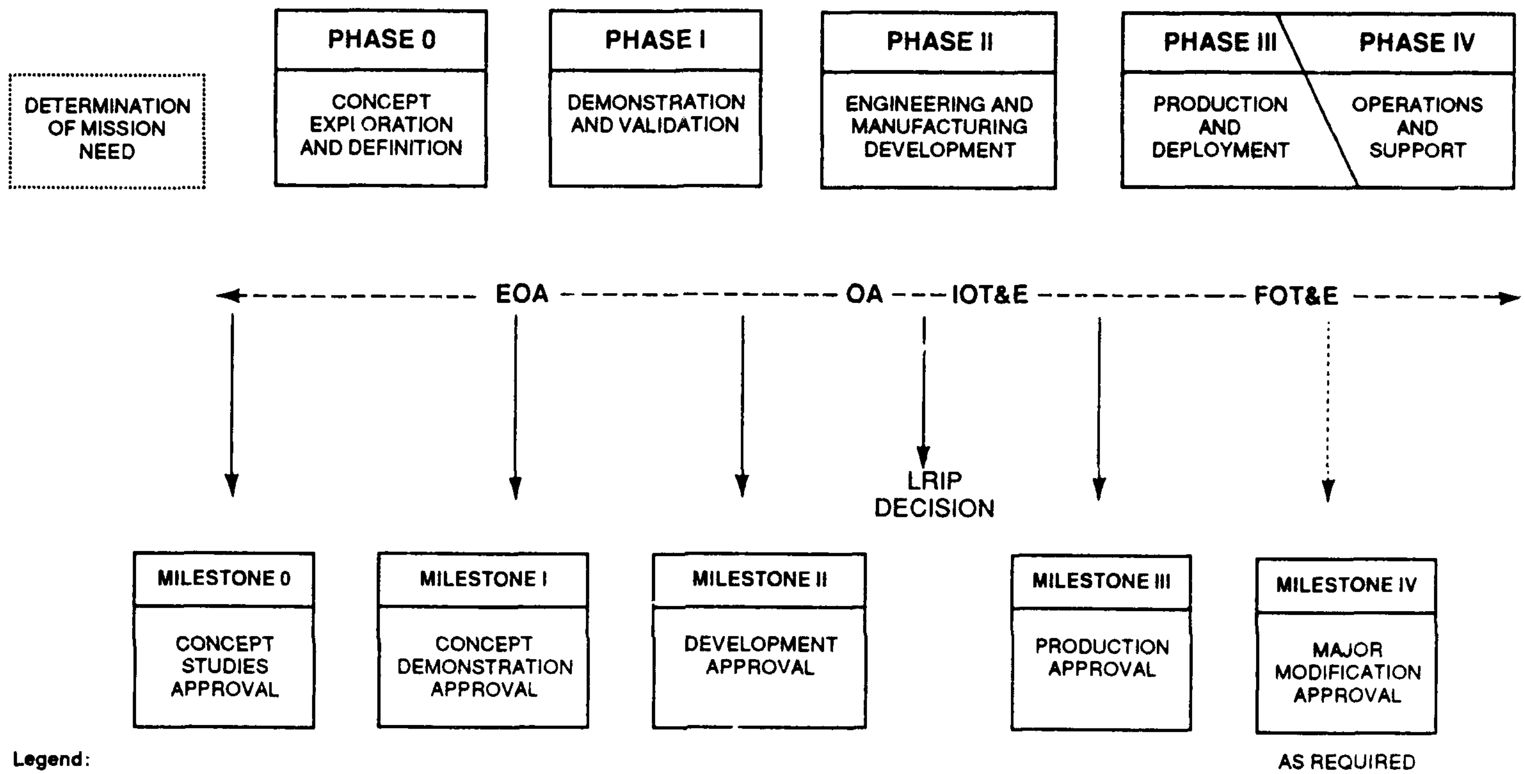
Test and Evaluation in the Acquisition Process

Each phase of the acquisition process provides a way to advance new findings, ideas, or opportunities in transforming stated mission needs into well-defined, system-specific requirements. Milestones are established at the end of each phase to assess the program's status, to assess the acquisition plan for the next phase, to manage risk, and to decide if the program should be continued, redirected, or terminated.[1]

This chapter defines the tasks to be accomplished within each phase of the acquisition process, then describes the focus of the system program office responsible for developing the electronic combat system. It also shows where operational test and evaluation is conducted to support the acquisition process and the type of information provided to the decision makers at each milestone decision point. Finally, this chapter points out where the T&E tools are used to support the EC test process within each phase. We begin by determining the mission need, then proceed through each phase in the acquisition process (fig. 10).

Determining Mission Need

Before entering the concept exploration and definition phase, the MAJCOMs will have to document how the current capabilities are deficient in meeting the mission need. If a solution cannot be reached through nonmaterial options such as changing operational doctrine, tactics, or training, then a mission need statement describing the deficiency in broad terms is prepared. It will be the Joint Requirements Oversight Council's job to review the MNS and confirm that a nonmaterial solution is not available. The council has the authority to validate the MNS and forward it to the milestone decision authorities for their use in making program decisions. Once the mission need has been validated, the objectives of the EC system can be established as well as the minimum acceptable performance requirements. These requirements will form the basis of the requirements process and remain consistent with the initial MNS. The quantitative and qualitative performance requirements that are established for the system will be documented by the MAJCOM in the operational requirements document (ORD).



Legend:

EOA = Early Operational Assessment
OA = Operational Assessment
IOT&E = Initial Operational Test and Evaluation
FOT&E = Follow-On Test and Evaluation
LRIP = Low-Rate Initial Production

Source: DOD Instruction 5000.2, *Defense Acquisition Management Policies and Procedures*, 23 February 1991, 2-1 (revised).

Figure 10. The Acquisition Phases, OT&E Stages, and Milestones

The ORD will also contain a description of how the system will be operated, deployed, and supported by the MAJCOM.

As the program progresses through successive milestone points, the measures and system performance requirements will increase in number and become more detailed. It is here that M/S can be used to assist in the requirements process by deriving the initial mission-level requirements and analyzing the cost and performance trade-offs. Furthermore, as the EC system progresses through each phase of the acquisition process, M/S can be used to update the requirements prior to each milestone. The MAJCOM will document any updates or changes to the requirements in the ORD.

In addition to identifying mission needs or deficiencies, the MAJCOM will be summarizing the threats and the projected threat environment in the MNS. The basis for this information rests with Defense Intelligence Agency (DIA)-produced and -validated threat projections that extend 10 to 20 years into the future. Furthermore, the DIA-produced threat documents will be used to support a system threat assessment and to determine the program costs and operational effectiveness estimates.

Concept Exploration and Definition

The main objective of the concept exploration and definition phase is to study all proposed solutions, determine key system performance and design characteristics, and appraise the operational capability and effectiveness of each solution. It is here that design trade-off studies take place to analyze proposed solutions that satisfy the need stated in the MNS. Computer simulations, past experience, and knowledge from previous testing assist in defining and selecting a preferred system concept. The proposed technology to meet the operational need is assessed to see if it is achievable and to determine key mission-level performance requirements. It is during this phase that an electronic combat digital system model may be developed by the system program office to study proposed alternatives.[2] This model will have enough detail to be used in a mission-level simulation to make design studies and to help identify the most promising concept. One of the keys to the EC test process is that this model can be used to support the requirements process. Once developed, the EC digital system model should be usable to determine the mission-level requirements throughout the life of the system.

During this phase, the SPO may also use mission-level computer simulations developed by the MAJCOM or other agencies to analyze the operational scenario and the predicted performance of proposed alternatives. In addition, breadboard components of the proposed technologies or prototype hardware can be installed in airborne laboratories to generate data in an open-air environment.[3] It is important to keep in mind that the SPO will not be testing

or evaluating any actual EC system hardware from the proposed solutions. EC system hardware will not be examined until the next phase of the acquisition process.

Testing technology prototypes in an open-air environment provides the opportunity to demonstrate the performance of the proposed solutions in a more realistic test environment than can be obtained in a ground-based laboratory. The data generated from the airborne laboratory can be used to assess the performance of candidate technologies, update the system models, and compare the performance with the pretest predictions from the computer simulations.

Along with inputs from the OTA, the SPO will identify the initial test resources that are required to support developmental and operational testing. Any deficiencies will be pointed out to the test investment-planning process. Identifying the deficiencies this early in the program should give enough lead time to make available the necessary test resources for developmental and operational testing.

During the concept exploration and definition phase, the OTA will be fashioning an early operational assessment for the specific EC system. The EOA can vary from program to program depending on the objective and level of involvement of the OTA. Throughout this phase, the OTA will be responsible for assessing the operational impact of the proposed solutions, providing an advisory input to the source-selection officials, and developing an overall OT&E strategy for the system.[4] This is also the point where critical operational effectiveness and suitability issues are developed to become the focus for OT&E. These COIs will be generated from the user's stated requirements and will provide the basis for the test objectives. Furthermore, because of the possibility of using contractor- or MAJCOM-developed models or simulations, the OTAs would be remiss if they did not monitor the M/S development. By monitoring the development of the models, the OTAs can ensure that the models are impartial and accredited for their specific use.

To support the milestone I decision, the MAJCOM develops a COEA that includes a broad range of alternative solutions that satisfy the mission need. AFR 57-1, *Air Force Mission Needs and Operational Requirements Process*, states that "the COEA should define the performance and operational characteristics most affecting mission accomplishment so program design and cost objectives can be established for Phase I."[5] The COEA should also clearly spell out why acquiring a new system is preferred over modifying an existing system. These early estimates are expected to be quite rough due to the difficulty of obtaining accurate organizational and operational cost projections of a system that is still in the concept phase.

In addition to quantifying the probability of mission success for each proposed solution, the MAJCOM will be developing mission-level measures to address the COEA objectives. As the system progresses through the acquisition process these high-level mission success MOEs should not change. In most cases the data used to address these MOEs will be aggregated from

lower-level MOPs that can be supported by actual test data. As the EC system proceeds through the acquisition process, the data used to evaluate the MOPs and the way the data is collected will change as more complex simulations are run, to testing the actual system in hybrid GTFs, and to eventually testing the system in the field.

It is also during the concept exploration phase that the MAJCOM prepares the initial system threat assessment. Here the threats to the proposed system concept are assessed and documented in the system threat assessment report (STAR). By tailoring the STAR to the specific system concept, the assessment identifies any potential or projected capabilities that the enemy could use to defeat, destroy, degrade, or deny the effectiveness of the proposed system.[6] The threat information documented in the STAR will be validated by the appropriate intelligence agency and will be made available to the milestone decision authority prior to each milestone decision, beginning with milestone I.

At the end of the concept exploration phase, the results are reviewed and approved by the program decision authority. The review will confirm that the study supports the need for a new program and that the threat assessment has been validated. The decision authority will also ensure that the EC system requirements have been refined, an initial assessment of the cost and development risk has been made, and adequate test resources can be made available to support the test program. Finally, the decision authority will want to see that a test plan, with exit criteria, has been developed for the demonstration and validation (dem/val) phase.

Demonstration and Validation

The aim of the demonstration and validation phase is to conduct technology demonstrations and to build and test prototypes of the EC system. The developing contractor may develop a detailed version of the EC digital system model for use in making performance predictions in the proposed mission scenario. These predictions will be used to refine the design of the EC system. The contractor will also test an engineering prototype of the EC system to assess the technologies needed to support their proposed solution and design concept.

During dem/val, the developing contractor will focus his testing on identifying and solving design risks and demonstrating the resolution of those risks. To support developmental testing, the contractor can build an engineering prototype of the preferred EC system by replacing certain components in the EC digital system model with hardware components developed during dem/val.

This engineering prototype will usually be integrated with a computer simulation of the host aircraft and the functional capabilities of the onboard avionics systems. The engineering prototype can then be tested in the

contractor's system integration laboratory (SIL) before any prototype components are tested in government test facilities. Contractor testing will focus on identifying hardware and software problems, and refining system performance.

Once the contractor has finished building and testing the EC digital system model or engineering prototypes, the SPO is invited to participate in or to monitor further contractor testing. Data is generated to make performance trade-offs and to identify the preferred design. The SPO can then study performance predictions from the engineering prototype to ensure that the proposed system design meets the needs of the user and validates the proposed system concept. The SPO can also use performance predictions to assess the operational effectiveness and suitability aspects of the design.

The SPO will be directing most of its attention to assessing the performance of the components, subsystems, or engineering prototypes. The information that is gathered will be used to verify that performance is as predicted, that the proposed design can indeed meet the user's requirements, and that technologies critical to the design can be incorporated into the system at acceptable risk. The SPO will be using engineering assessments and computer simulations to assist in setting performance requirements and objectives for technical performance goals.

Results from computer simulations will be used to demonstrate that milestone exit criteria have been achieved and to establish performance criteria and objectives for milestone III. Computer simulations will also be used to determine certain mission-level measures that cannot be directly measured in the hybrid GTFs or the field environment.

Reliability and maintainability (R&M) data will also be collected and evaluated to make sure the reliability growth plans meet the R&M goals. The SPO will be defining and integrating electronic warfare vulnerability assessment (EWVA) objectives into the DT&E plans to assess system vulnerabilities and susceptibilities to the threat environment. Furthermore, the SPO will form and chair a test planning working group (TPWG) that will serve as a medium to discuss the development of the test and evaluation master plan with the appropriate test agencies and contractors.

Once computer predictions of the system's performance are made, the developing contractor or the SPO may also want to test the prototype in a hybrid GTF to assess its performance against man-in-the-loop threat simulators. Results from this testing can be used to verify certain design specifications, calibrate models, or substantiate pretest performance predictions. The SPO may also take the prototype system to a measurement facility where data can be gathered on antenna patterns and on the host aircraft's RCS and IR signatures. This information is needed for use in computer simulations and the hybrid GTFs.

Usually any field testing of a prototype system during dem/val can only be accomplished in an airborne laboratory or test aircraft. Testing the prototype in the field environment can subject the system to phenomena that can only

be investigated under actual flight conditions. Results from testing in the field may lead to changes in system specifications or may result in a redesign of the system. This is also a good time to again ensure that any new test resources or upgrades to existing test facilities are identified and made ready when full-scale testing begins. The product from the SPO's efforts in the dem/val phase is a set of documents that contains detailed cost, schedule, and system performance objectives and parameters.

During dem/val, the OTA will continue the EOA activities by providing the decision makers with an assessment of the EC system's potential to meet the user's mission requirements. Problems uncovered during the EOA that could impact the system's operational capability must be identified and rated so the decision maker can assess any high-risk areas. Early involvement by the OTA can provide the opportunity to influence the system's development and to make sure the user's needs are not overcome by schedule or cost motivations in the push to produce a system.

Initial EOA activity will involve a thorough review of operational requirements, critical operational issues, and the program documentation (e.g., PMD, MNS, ORD, STAR, and COEA).[7] The critical operational issues will be reviewed and refined to verify that the test plan addresses the required operational characteristics. In assessing the status of the documentation, the OTA will look for completeness, clarity, and consistency between documents; sufficient and rational user requirements; and other factors that could affect testability.

The OTA must work with the user to ensure the evaluation criteria are complete and testable. User evaluation criteria should be specified for both the mission- and system-level measures. The evaluation criteria should also be documented prior to the start of OT&E. The OTA will assess the test schedule to see if it is adequate in terms of time and that the availability of test articles is sufficient to meet the needs of OT&E objectives.

In this phase, the OTA will be calling on the intelligence community to

- provide DIA-validated intelligence support to the models and simulations,
- provide analysis of the projected threat environment,
- determine the most realistic threat layout for the simulators in the hybrid GTF or on the test range,
- provide support in developing and validating the threat scenario,
- supply technical data on the threats of interest, and
- assist in range improvement programs.[8]

Once the threats have been identified and tailored to the proposed system concept, the OTA will determine availability of threat simulators to replicate, to the best of their ability, the threat environment in either the hybrid GTFs or in the field.

In addition to the threat resources, the OTA will assess the availability of other test resources needed for the evaluation and document any shortfalls. A test program outline (TPO) will be prepared as a resource management and

programming plan to ensure resource requirements are programmed into the budget cycle. Alternate courses of action will be planned in the areas where the test resources will not be available. The OTA will also make sure that the TEMP includes a description of the test resources needed to support the operational evaluation.

The early operational assessment will include a review of the operational aspects of the proposed approach and will identify programmatic voids that could impact the ability of the system to meet user requirements. Along these same lines, the OTA will assess the progress of the system's development and identify significant trends in the development process that could impact the system's ability to meet user requirements.

During dem/val there will be few, if any, test articles that can be used to support the EOA. Basically, the operational test agency is relegated to an over-the-shoulder assessment of the EC system and the activities of the development program. The OTA must work with the SPO to ensure the proposed system concept will meet the user's operational requirements. When gathering data to support the EOA, the OTA will have to depend on the results from the SPO's or contractor's M/S efforts as a source of information. However, to have confidence that the results are not biased in favor of the contractor, the OTA must understand how the model operates and whether it has been accredited. Other sources of information include monitoring contractor testing and technology demonstrations, reviewing contractor technical performance documents, and sharing data from prototype testing if available.

The milestone II review of the dem/val results should provide confidence that the technologies and the critical development processes for the EC system are achievable. The review should further provide assurances that the threat assessment and mission need are still current and valid. It is at this point that the MAJCOM will provide a detailed COEA that analyzes and evaluates a range of alternatives. This COEA should establish objectives that point out the minimum acceptable performance and the maximum allowable cost, or some combination of performance and cost, document the compromises used to arrive at the performance and cost objectives, and analyze the consequences of terminating the program.[9] In addition, the MAJCOM will perform a COEA sensitivity analysis to identify any critical sensitivities of the EC system's effectiveness to test restrictions, such as safety constraints or test resource limitations. After the program decision authority grants approval to proceed into the engineering and manufacturing development phase (see fig. 10), the MAJCOM develops exit criteria for the next phase. Then the program decision approves the production of prototype systems to provide test articles for operational testing.

The objectives of the next phase in the acquisition process are to assure that the design risks have been solved, to verify the adequacy of the proposed manufacturing processes, and to provide realistic production costs and schedule estimates.

Engineering and Manufacturing Development

After approval from the program decision authority to proceed, the engineering and manufacturing development phase begins by

- developing a production prototype,
- performing contractor testing,
- starting the initial low-rate production,
- installing the EC system in its host aircraft, and
- executing developmental and operational testing.[10]

It is in this phase that a complete and fully functional EC system is developed from requirements that evolved during the dem/val phase.

As described in DODI 5000.2, *Defense Acquisition Management Policies and Procedures*, the purpose of the engineering and manufacturing development phase is to transform the most promising design approach into a firmly established, producible, and cost-effective EC system design; to substantiate the manufacturing or production process; and to demonstrate through testing that the contract specifications have been met and that the system capabilities satisfy the mission need and achieve the stated performance goals.[11] Also, the reliability and maintainability growth goals can be reassessed by using computer simulations and actual test results from the production prototypes, to ensure that R&M performance objectives will be satisfied at the milestone III decision.

During this phase, the EC digital system model will be updated and calibrated by the SPO with production prototype test data. This will give the model the ability to support further testing by characterizing the system's full performance range and effectiveness. The updated EC system model can also be used to extend the test results to other test conditions and scenarios, assess proposed design changes, and provide data that address the COEA objectives. The model can also be used to support pretest planning, to structure test trials, and to update the predicted system performance values.

In the engineering development phase, the contractor will start with the engineering prototype components developed during dem/val and as long as the components are a sound design, the contractor can modify or gradually build them up into a fully functional production prototype of the EC system for testing in the contractor's system integration laboratory. The production prototype system can then be interfaced with real-time simulations or actual hardware from the host aircraft and other avionic systems. This integrated configuration can then be stimulated by threat signals to test and correct any hardware and software problems. By using the SIL, the contractor can evaluate the performance of the production prototype and the compliance with system specifications. Once the EC system prototype has been tested at the contractor's facilities, it can proceed to government testing for a more thorough evaluation.

The SPO will be directing its attention to testing the production prototype to ensure that the engineering is complete and that the contractor has met contractual specifications. A test plan developed by the contractor and SPO will be the means through which this is accomplished. By collecting data to evaluate the accomplishment of development objectives, design problems will be identified and solved, system software tested, compatibility and interoperability with other aircraft systems checked, and R&M results examined. If there have been significant changes to the performance or costs to the system, the SPO will also make sure that the data needed by the MAJCOM to update the COEA has been collected and is ready for the milestone III review.

The SPO begins the developmental test process by using M/S to predict the performance of the EC system under various test conditions and to complete any remaining pretest planning factors. The testing then proceeds to the contractor's SIL for compliance testing on a production prototype. Here the SPO monitors tests that confirm that the system performs as designed and ensures that any identified hardware and software problems are fixed.

The production prototype is then placed in an uninstalled hybrid GTF to confirm that problems identified in previous testing have been corrected and that the specified performance objectives for the EC system have been achieved. If the system is designed to use electronic countermeasures (ECM) or IR countermeasures to oppose the threat system then based on the evaluation criteria, the hybrid GTF can confirm if the countermeasures used against the threat are effective. Examples of the type of testing that can take place here include the capability to process a high-density signal environment, to determine system effectiveness in terms of inducing tracking errors and missile-miss distances against MITL threat simulators, and to verify that data received from several sensor locations is correctly fused into a single output for display. Once again, the SPO will have to take the production prototype to the measurement facilities to establish new or updated values for antenna patterns and aircraft RCS and IR signatures for use as inputs to the simulations performed in the hybrid GTF.

By testing in the installed hybrid GTF, the SPO can evaluate the performance of the EC system while the system is installed on the host aircraft. This may be the first opportunity to test the EC system when it is installed on its host aircraft and integrated with onboard avionics. Developmental testing is conducted in the hybrid GTF to evaluate the integrated performance of the EC system as part of the total avionics suite. Examples of installed testing include

- electromagnetic compatibility (EMC) with other systems on the aircraft,
- sensor operation,
- locating and displaying the threat system to the aircrew,
- data flow to EC system processors and output displays, and
- confirmation of RF isolation between the receive and transmit antennas.

The installed hybrid GTF can also identify major problems during the preflight of the system on the day of the flight and provide a method to analyze problems encountered during flight.

Field testing follows ground testing and provides the opportunity for the SPO to establish performance values for the EC system in an open-air environment. Once again, key system-performance parameters are tested in representative mission scenarios. They begin with one-versus-one engagements and progress to scenarios with multiple-threat engagements using all available test resources. Examples of data collected during flight testing include countermeasure effectiveness against MITL threat simulators, angle of arrival accuracies, threat-detection ranges, correct threat identification, and data for R&M analysis.

Because many of the test resources needed to support DT&E and OT&E are the same, testing can be conducted in a combined effort, generating similar test data used to support each other's test. Although DT&E and OT&E are still separate and distinct test programs, the benefit of a combined test program comes from the cost-effective use of test resources and from reducing the time to test the EC system.

Although there are similarities between DT&E and OT&E, there is one important difference that has to be taken into consideration when operational testing proceeds beyond the LRIP decision. That is the use of development contractors in OT&E. The *US Code* allows the use of development contractors in all phases of DT&E. However, as pointed out in chapter 3, Title 10 of the *US Code* prohibits the involvement of development contractors in OT&E when proceeding beyond the LRIP decision, except to the extent that DOD plans call for their involvement in the operation, maintenance, and support of the system when deployed.[12] Because of this restriction, the OTA will have to be extremely cautious of contractor involvement when dedicated IOT&E begins.

Planning a combined test requires close coordination between the SPO and OTA to ensure the test conditions and data requirements necessary for both test programs are satisfied. In the initial stages of the test process, DT&E test events will have priority in evaluating the critical technical and engineering-level performance measures. The OTA will participate in this stage mainly as an observer, while becoming familiar with the system and identifying test data that can be used to support OT&E. The next segment of the test will include test events which will produce data that can be shared between the developmental and operational test programs. This combined approach should not interfere with either test program. At the completion of DT&E, the SPO will certify that the EC system is ready for dedicated OT&E. The last stage of testing is then conducted by the OTA and contains test events dedicated to IOT&E.[13]

After entering the engineering and development phase, the OTA will begin by making an independent operational assessment (OA) of the system's potential to meet the user's requirements and its progress toward becoming an operationally effective and suitable system. The purpose of the OA is to

support the LRIP decision (see fig. 10). Again, the role of the OTA during the OA will mainly be that of an observer monitoring the progress of DT&E. The OA will be based on all relevant data from developmental testing, user trials, interim results, and computer simulations. Many of the same activities and program reviews that took place during the dem/val phase will be continued by the OTA in the operational assessment. This will include significant developmental trends affecting the system's ability to meet the mission need, programmatic voids, areas of risk, and adequacy of test requirements, and the ability of the program to support adequate operational testing.

During the OA, many of the planning activities that go into developing an operational test plan are accomplished. This is also the time to identify the necessary test resources, to finalize the proper mix of test tools, and to form the test team.

If available during the OA, the updated EC digital system model can help with the pretest planning step for IOT&E and to make performance predictions to compare with test results from the hybrid GTF and the field test. If not already established, the mission- and system-level measures are developed or at least refined along with the essential data elements needed for analysis. This includes the elements needed from field testing to validate and accredit the models. The OTA may also be tasked to support the MAJCOM's analysis of the system's cost and performance trade-offs by providing data to run in the MAJCOM's COEA models. If this is the case, then the test elements needed to support this effort must be included in the IOT&E test plan. This initial use of computer simulation is used to gain insight into the EC system's response to the threat. It is not intended to determine or evaluate the effectiveness of the system.

Using the MAJCOM-developed computer simulation of the planned operational scenario, the test manager can generate the field-test scenarios and identify the data items that must be described in the IOT&E test plan. The test manager must remember that when using M/S in OT&E to support a decision to proceed beyond the LRIP, the involvement of development contractors in conducting or assisting in the test, or as advisors, is restricted by Title 10 of the *US Code*.[14] Therefore, no development contractor involvement or the use of development contractor facilities will be relied upon in IOT&E. It is for this reason that the contractor system integration laboratory will not be integrated into dedicated IOT&E test plans.

The operational test agency must make sure everything is in place and ready for dedicated initial operational test and evaluation. Then after the SPO certifies the EC system "ready," the OTA is cleared to conduct dedicated IOT&E on a production-representative system.

The EC test process for OT&E looks very similar to that of DT&E, but the focus of operational testing is on answering the COIs instead of verifying technical system performance. Furthermore, the test scenarios used in OT&E will be more representative of the proposed operational missions than of the very controlled one-versus-one engagements conducted during DT&E.

Once dedicated IOT&E has started, it is essential that a production-representative system be used because it provides the most valid test approach to evaluate operational effectiveness and suitability objectives. Then, through the application of a sound EC test process, the COIs refined during the dem/val phase can be addressed, and the OTA can ensure that an operationally effective and suitable EC system is delivered to the using command.

The OTA may initially take the production-representative system to an uninstalled hybrid GTF where data will be collected to answer operational effectiveness and suitability objectives. The type of test data that is to be collected will depend on the measures, but in general it will be similar to that collected in DT&E. It is the testing philosophy that differs from developmental testing in that the scenarios are validated and the threat densities used for the evaluation are operationally representative. In addition, the OTA can use the hybrid GTFs to complement field testing by providing an opportunity to pretest the mission scenario before testing in the field. This pretest will allow the OTA to further refine the test plan and make more efficient use of the available field range time. Capt William Farmer and Col John Nagel further state that

> the test director can identify sensitive areas which will require special attention in the field, refine instrumentation requirements, revise tactics, and identify the impact of the *human threat system operator* on the effectiveness of the EW [electronic warfare] system under test.[15]

Next the OTA can test the EC system in an installed hybrid GTF where the system's performance can be evaluated while integrated with the host aircraft's avionic systems. The testing methods in this facility are similar to those used in DT&E. The exception is that the threat environment is more representative of an operational environment, and the focus of the test is to address the COIs.

Field testing gives the OTA the opportunity to evaluate the EC system with its host aircraft under natural environmental operating conditions. Real-world phenomena such as terrain effects, multipath propagation, and commercial electromagnetic interference effects (radio broadcasts, microwave transmissions, etc.) can only be encountered in the field environment.[16] Interference and system incompatibilities due to these circumstances will usually show up in the field test and not in the computer simulations or the hybrid GTFs. Field testing provides the OTA the opportunity to see how the operator, functioning under the pressures of an actual flight environment, can operate the EC system and interpret the system's output.

It is during field testing that the OTA can adequately address system suitability in a realistic environment. This area cannot be addressed sufficiently with computer simulations or in a ground test facility. Also, if the EC system is designed to detect the presence of missiles fired at the aircraft, then field testing can provide an environment to conduct live firings of missiles at the aircraft, from a safe distance, to test the complete end-to-end performance of the EC system. Once again testing in the field is quite similar to the

testing accomplished during DT&E with the main difference being a more operationally representative test scenario with the focus on addressing mission-level test objectives. Any system problems encountered during testing will be reported to the SPO for resolution at the conclusion of testing.

Prior to the milestone III review, the MAJCOM will be reviewing the COEA using test results from both developmental and operational testing to confirm the decision that the selected system is still the most cost-effective approach to satisfying the operational requirement.[17] Any analysis done to support the COEA process will only be used to update the current COEA. Unless there are sufficient changes to the performance and cost estimates, a new cost and operational effectiveness assessment is not required. If it is discovered during the premilestone planning process that changes justify a new COEA, the milestone decision authority will then explicitly state the analysis that needs to be accomplished to update the elements in the COEA.

At the milestone III decision, test results will be reported so that a decision can be made as to whether to produce the EC system. Decision makers will be using the test results from both developmental and operational testing in making their appraisal. They will also be verifying that the proposed design and manufacturing processes are stable, realistic estimates of production costs are established, and a plan to deploy and support the system is complete. Additionally, the decision authorities will want to see that the final cost, schedule, and performance objectives for production and deployment are documented. With a favorable decision by the program decision authorities, approval is given to enter the production and deployment phase (see fig. 10).

Production and Deployment

After reaching the production and deployment phase, the EC system enters into full-rate production. It is during this phase that the using command will declare the system ready for initial operational capability (IOC). IOC is based on criteria defined during the previous phase. The full-rate production systems will be the ones deployed to operational units and used in the next stage of OT&E.

The objective of the production and deployment phase is to make sure an efficient and stable production process is established with an adequate technical support base. In addition, the user must be satisfied that the intended mission need has been met with the capabilities of the system. If a new requirement is identified during this phase and it requires a major modification to the system, then an additional milestone (milestone IV) is necessary. System modifications may be necessary to correct deficiencies; to make improvements to the system; to compensate for new intelligence on the threat; to reduce life-cycle costs; or to improve system reliability, maintainability, and availability.[18] To confirm any of the modifications and to substantiate that system specifications have been met, DT&E will be conducted. Developmen-

tal testing may also be required to demonstrate an operational capability or to identify requirements for additional operational testing.

DT&E will evaluate and verify any changes in the hardware and software through a limited number of installed ground tests and flight tests. Again, the SPO will begin the EC test process with pretest planning to evaluate the changes to the system. Testing will then proceed through the various test tools as required to support program decisions and to update the EC digital system model so it exhibits the characteristics of the production system.

If there are major changes to the design and function of the system, then the SPO will have to verify that the EC system is still effective against MITL threat systems. The purpose for conducting DT&E on the modified production system is to ensure that the performance and effectiveness requirements established for the system can still be achieved. This testing will first be accomplished at a hybrid GTF, then proceed to an installed hybrid GTF where the system's interfaces and interoperability requirements with the host aircraft's avionic systems can be evaluated. The installed hybrid GTF will also be used to pretest the system prior to any field testing. Again, measurement facility testing may have to take place if there were changes to the antenna's shape or function or its location on the host aircraft.

Next, the SPO will perform the required field testing with the EC system to make certain the production system satisfies the user's requirement. The *Air Force Electronic Combat Development Test Process Guide* states that "this testing may include new threat simulators that are more representative of the actual threat and may employ larger test scenarios as more test assets are available."[19]

If any operational testing is required during the production and deployment phase, it is referred to as follow-on operational test and evaluation. Testing is conducted because the proposed mission or threat environment may have changed to the point where it is necessary to see if the system is still effective. FOT&E is used to evaluate any modification or design changes made to the production system as the result of deficiencies found during IOT&E and to ensure it continues to meet the user's operational needs. The EC system's operational effectiveness and suitability objectives are further evaluated to identify any system deficiencies or needed modifications. By increasing the number of test events and test conditions, FOT&E can also be used to refine the operational effectiveness and suitability results obtained during IOT&E.

In this phase, the OTA will tailor the FOT&E to examine those areas that are required for a milestone IV review. As in the previous phase of testing, the OTA will start the EC test process with pretest planning to determine the objectives of the test and the proper mix of test tools. Depending on the objective of the test, the OTA may take the EC system to a hybrid ground test facility to evaluate its effectiveness against an updated threat environment or may just take it into the field to reaccomplish portions of the previous evaluation. In any case, the testing performed in FOT&E will be comparable to that conducted in IOT&E and will proceed in a similar manner.

The purpose of the milestone IV decision is to give approval to initiate a major modification (see fig. 10). If approval is given to begin an upgrade or modification to a system that is in production, then the decision authority may require a COEA. If a COEA is required, then the decision authority will specify the elements that will require further analysis. As part of the program review, the decision authority will make sure that all alternatives to the modification have been considered. They will also confirm that the performance objectives have been met and any new assessment of the threat has been validated. The decision makers will be basing part of their conclusions on performance of the system in the operational units as well as the results from testing. They will be examining and determining if the required technologies and production processes have been clearly identified and can be attained. Finally, the program decision authority will review the affordability of the program and the availability of the resources needed to support the program.

Operations and Support

Once the EC system is fully operational, it enters the operations and support phase of the acquisition process. There will be some overlap between this phase and the production and deployment phase (see fig. 10). The operations and support phase signals the transfer of the management responsibilities from the SPO to the system program manager at the logistic center. The EC system remains in this phase until it is retired from the inventory.

The objective of testing in this phase is to ensure that the EC system continues to meet the user's mission requirements and to identify any deficiencies or modifications needed to improve the performance of the system. To confirm the performance improvements and evaluate the system's operational effectiveness, FOT&E may have to be conducted with several of the T&E tools. The EC test process will again be used to plan, conduct, and report the test results to the decision authorities.

This concludes the description of the tasks to be accomplished in each phase of the acquisition process and where the T&E tools fit to support the process. As this chapter has shown, OT&E is an iterative process that overlays the developmental test process with a mission-level evaluation. The responsibilities of the participating, operating, and supporting commands, and the OTAs must be integrated into a coherent test process that supports the acquisition strategy. The test and evaluation master plan is the document that integrates all T&E and makes certain that the test program is consistent with the acquisition process.

The TEMP furnishes the linkage between the test schedule and program schedule. It provides the basic structure, test philosophy, and direction that

go into putting together a comprehensive OT&E test plan.[20] The TEMP should be updated annually to reflect any changes to the requirements, schedule, T&E tools, and so forth, and reviewed prior to each milestone decision point.[21] The test manager can use the TEMP as an instrument to document and lay out the requirements for OT&E. Before the TEMP is approved and signed, there must be concurrence and agreement with the schedule, funding, testing, resources, and so forth between all agencies involved with the T&E of the EC system. Once signed the TEMP becomes the road map that key decision makers will use when following the testing to be accomplished in each phase of the acquisition process. As the system matures and various stages of OT&E are completed, the test manager will have to ensure the OT&E portions in the TEMP are updated and that all changes to the TEMP support the EC test process. The test manager must be particularly cautious that changes to the program schedule do not destroy the test process.

Unless all organizations involved in the EC test process complete their assigned responsibilities the EC test process will not work. For example, the OTA cannot derive the operational test requirements until the MAJCOM has defined the operational scenario and the mission need.

Finally, it should be noted that the test manager does not have to use every T&E tool described in this study. Depending on the objectives of the test and the status of the EC system, the test manager will select just the test tools that are needed to satisfy the objectives. For example, during FOT&E the test manager may not need to go to the uninstalled hybrid GTF if the system is already installed in the aircraft for ground testing. Or perhaps testing on the field test range may be all that is needed to address the test objectives.

Notes

1. *Air Force Electronic Combat Development Test Process Guide* (Washington, D.C.: Department of the Air Force, 1 May 1991), 4 (hereafter cited as *AF EC Test Process Guide*).
2. Ibid., 37.
3. Ibid., 39–40.
4. Lt Col Greg A. Mann, *The Role of Simulation in Operational Test and Evaluation*, Research Report no. AU-ARI-83-10 (Maxwell AFB, Ala.: Air University Press, August 1983), 9.
5. AFR 57-1, *Air Force Mission Needs and Operational Requirements Process*, 15 November 1991, 38.
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7. *AF EC Test Process Guide*, 45.
8. Col John Clark, Air Force Intelligence Agency (AFIA), Kirtland AFB, N.Mex., interview with author, 11 February 1992.
9. DODI 5000.2, 4-E-7.
10. *AF EC Test Process Guide*, 50.
11. DODI 5000.2, 3-21.
12. *United States Code* Annotated, Title 10: *Armed Forces*, 1992 supplementary pamphlet, sec. 2399 (Saint Paul, Minn.: West Publishing Co., 1992), 405–6.

13. AFR 80-14, *Test and Evaluation*, 3 November 1986, 7.
14. Title 10, *Armed Forces*, 405–6.
15. Capt William D. Farmer and Col John F. Nagel, "Electronic Warfare System Operational Test and Evaluation," final report (Kirtland AFB, N.Mex.: Air Force Test and Evaluation Center, March 1980), 28.
16. *AF EC Test Process Guide*, 82.
17. Memorandum, ASD/PA&E, subject: Incorporating Cost and Operational Effectiveness Analysis (COEA) Measures of Effectiveness (MOE) into Test and Evaluation, Draft Implementation Guidelines (Revised), undated.
18. *AF EC Test Process Guide*, 60.
19. Ibid., 62.
20. AFR 55-43, *Management of Operational Test and Evaluation*, 29 June 1990, 22.
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Chapter 5

Summary, Conclusions, and Recommendations

The introduction of EC systems into the force structure has been due in part to a reaction to the enemy's defensive systems. Initially, EC systems were developed under a "quick-reaction" program that attempted to satisfy the immediate need of countering the enemy's threat systems. Because of the urgency to find countermeasures, any T&E that took place ended up being more of a "trial-and-error" process that attempted to identify the best method to counter the threat. The T&E tools, such as those described in this study, either did not exist or were not representative of the actual threat environment and therefore were of little use in evaluating the effectiveness of the EC system. As a result, the T&E philosophy that evolved has been haphazard and has lacked any resemblance to a standardized test process. What has evolved and is still being practiced is a test process that follows a "test-fix-test" method. This works well in supporting the development of the EC system but does not support the intent of OT&E.

When several EC systems failed to meet the user's requirements, a broad area review was initiated to determine if there were deficiencies in the EC test process. One of the findings from the review stated that EC system testing lacked the discipline and essential elements of a scientific test process. Furthermore, the broad area review determined that due to the lack of a disciplined and standardized test process, meaningful test results necessary to support production decisions were not being produced. In addition, the Department of Defense inspector general reviewed several OT&E programs and concluded that OT&E would have more of an impact on acquisition decisions if it did not get caught up in the test-fix-test scenario that began in developmental testing.

I have found that to add discipline and structure to the EC test process, there are certain limitations or challenges that must be addressed in order for the decision makers to be satisfied with the OT&E results. The first limitation has to do with testing the EC system in an operationally representative test environment. A test method must be devised to evaluate the EC system in a test environment that accurately represents the actual combat environment. This will give decision makers confidence in the test results when making a decision on whether to continue or terminate the program.

Decision makers want to know not only that the system meets the technical performance requirements but that it contributes to the overall success of the mission. Determining whether the system is effective and plays a significant part in the success of the mission is the purpose of OT&E. However, establishing mission-level test measures and criteria that evaluate the EC system's contribution to the mission have not been well defined or standardized. Mission-level measures are important to decision makers when considering the cost and effectiveness of one alternative over another.

Another challenge to the T&E of EC systems is the absence of complete intelligence on the latest generation of threat systems. The lack of complete intelligence has caused two problems for the OTAs. Both have to do with the technical details that describe the threat and its operation. First of all, this information is needed to build and validate the models and threat simulators. Without accurate threat simulators, a true assessment of the EC system's performance cannot be obtained. Second, this information is needed when designing an EC system that can identify and counter the threat system. If the technical details on the threat are unknown, then the design of the EC system cannot be finalized. If it is finalized before the necessary technical information on the threat is known, the EC system may be ineffective in meeting the user's requirements. As a result, the developer is often chasing down the latest information on the threat to incorporate into the design of the EC system. Furthermore, as new intelligence on the threat is received during developmental testing, the SPO will be attempting to integrate this information into the EC system by updating the hardware and software functions. Inevitably, the OTA ends up testing a system that is not quite representative of the production version and may have to test a system that has known limitations or shortfalls in meeting the user's requirements. When this happens, the OTAs wind up providing test results to the decision authorities that are not representative of the final system.

Finally, the OTAs are faced with the challenge of testing a system that is highly integrated and dependent on other onboard avionic systems. The integrated nature of the total avionics suite makes it difficult to assess the effectiveness of just the EC functions in contributing to the success of the mission. Furthermore, because of the dependence on other onboard avionics, the test scenario becomes more complicated, requiring both friendly and hostile players along with the associated C^3 network. To provide structure and discipline to the EC test process, these limitations and challenges must be addressed.

Conclusions

The solution rests with the proper application of the available T&E tools and scientific test methods. A scientific test process will provide the structure

and discipline that will produce the information that the decision makers are looking for to decide if the program should proceed to the next phase of the acquisition process. The test results help provide the knowledge to determine whether the EC system is meeting its performance objectives, and whether it is still an affordable solution. The scientific test process will give the decision makers the confidence that the test results reflect the way the system will work if deployed. In addition, it will help the OTAs avoid the test-fix-test scenario started in DT&E.

A well-defined test process starts with the selection of T&E tools needed to answer the test objectives. There is a wide range of tools that can be used in the EC test process, each tool having its own particular purpose in supporting the test program. The test manager must understand the functional relationships between the tools and how they support the EC test process. Furthermore, he or she must ensure that the tools are available at the start of each stage of OT&E and that they have been validated and accredited to provide credible test results for the evaluation. This study has identified three major categories of tools from which to select: modeling and simulations, hybrid ground test facilities, and field test ranges.

To add discipline and structure to the EC test process the test manager must apply the principles of a scientific test methodology to the operational evaluation. There are six fundamental steps (see fig. 7) to the scientific test process that can be applied to any EC test program. The test methodology can then be tailored in each stage of OT&E to support the decision makers with information at the appropriate milestone decision points (see fig. 10). The objective of the scientific test process is to facilitate effective test planning, test execution, and analysis of the test results. Furthermore, the EC test process depicted in figure 6 stresses the integrated use of M/S, hybrid GTFs, and field testing to evaluate the operational effectiveness and suitability objectives. The result is a disciplined EC test process that will produce the products needed to conduct an orderly OT&E. Also, by identifying the proper functional relationships between the T&E tools and emphasizing their role in the EC test process, many of the limitations or challenges to operational testing can be dealt with.

By implementing a scientific test process, the OTAs will have a much better idea of what to expect during the performance of OT&E. The scientific test process uses a methodology that forms pretest predictions that will give the OTAs an indication of what to expect before the test starts. Knowing what to expect from the EC system ahead of time will allow better preparation for the evaluation by the OTAs.

The test manager must identify the aim of OT&E in each phase of the acquisition process and focus in on where the T&E tools fit into the scheme of OT&E. The current acquisition process does provide the framework in which to base a structured test program. The five phases and milestone decision

points in the acquisition process are designed to make an orderly transition of broadly stated mission needs into system-specific performance requirements. Within each phase, the OTAs play an important part in estimating whether the proposed solution will meet the user's requirements by providing decision makers with information on the system's effectiveness and suitability. By implementing a scientific test process, OT&E will then become an excellent vehicle to make significant contributions to the acquisition process and support the intent of the decision makers.

However, much of what needs to be done is outside the purview of the OTA's scope and authority. Other than implementing a scientific test process, the OTAs have limited involvement and no control in the development of the system models, nor in upgrades to the test facilities and field ranges, nor in the certification that the EC system is ready for OT&E. This creates a major challenge for OTAs tasked with the OT&E of EC systems.

Recommendations

To establish a disciplined and structured test process for the acquisition of EC systems, I recommend the following.

1. **The OTAs institute the scientific test process outlined in this study.** This study highlights the particular functions performed by M/S, hybrid GTFs, and field testing to overcome many of the limitations and challenges associated with testing EC systems. It also provides a scientific test method that will provide discipline when determining the operational effectiveness and suitability of EC systems. Such a test process will give the decision makers the confidence and satisfaction that the test results reflect the way the system will work if deployed. The scientific test process will also help the OTAs avoid the test-fix-test scenario that began in developmental testing by better preparing the tester for the evaluation and by reporting the results from the evaluation at the conclusion of the test process. OT&E results can then support the intent of operational testing and provide the decision authorities with information to make acquisition decisions. By accepting this recommendation the OTAs will have a cost-effective and efficient method to test EC systems.
2. **Provide education and training on the scientific test process for EC systems.** The OTAs need to identify the personnel involved with EC system testing at all levels within their organizations so that they can receive training on the scientific test process. Training will facilitate the understanding of the EC test process and show how the results generated by the test process are used by the decision makers to support the acquisition process. This training can also reveal the purpose and application of the T&E

tools used to support the evaluation or assessment of EC systems. Training could also show how the test objectives are developed from the COIs, how quantitative and qualitative measures are developed, and where the evaluation criteria and data requirements come from. A vehicle already exists in which the necessary training could take place. That vehicle is the OT&E training course taught by AFOTEC at Kirtland AFB, New Mexico.

3. **Clarify the requirements in AFR 55-43, *Management of Operational Test and Evaluation*, to have the OT&E final report approved and signed 60 days after the last test event, and clearly state that the results from OT&E will not be released until the final analysis is complete.** To have a disciplined and structured test process, sufficient time must be allowed to complete the posttest evaluation. The test team should not be pressured into providing a final report until the posttest evaluation is complete. Currently, the last field test event that gathers test data is considered the last test event and according to AFR 55-43 a final report is required 60 days later. This undoubtedly will not allow enough time to complete any additional model accreditation efforts with field test results, to operate the models used to determine mission-level measures, to correlate the test results with the T&E tools, and to resolve any differences between the predicted and actual test results. In addition to these final posttest activities, the test team is preparing to disband and ship the unit resources (computers, office equipment, software, test items and equipment, etc.) to the appropriate agencies. The result can be a less than thorough and complete analysis of the test data. The last test event needs to be based on the event that completes the posttest evaluation phase and supports the evaluation of the EC system. Of course this event must be documented in the TEMP and the test plan so that it is clear when the last event will take place. As soon as this event is complete, the 60-day countdown to the final report can begin. This will allow the OTA the time needed to complete the EC test process. It gives the test team the time to complete the analysis of the test results without having to rush into writing the final report and preparing the OT&E briefing. In addition, it will give the test team a better opportunity to go back through the data to verify trends just discovered or explain why certain things happened at the conclusion of testing.

As might be expected, the OTAs have a responsibility to report the test results on the just completed phase of testing prior to the milestone decisions. If the final report is not ready for distribution, a provision has been made in AFR 55-43 that allows an interim summary report in the form of a message to suffice. It should summarize the evaluation in enough detail to support the decision makers. However, if the final analysis is not complete, then the OTA should not release any interim findings. Releasing the interim results before the posttest evaluation is complete compromises the integrity of OT&E and is

one of the reasons for the perception that OT&E cannot produce meaningful test results. The schedule should not drive the release of OT&E results. AFR 55-43 should clearly state that until the final analysis is complete, the results from OT&E will not be released.

Further Study

This study does not address the inadequacies in the T&E tools as they exist today. These issues are being worked through the various test range and facility improvement programs. Another problem area not addressed in this study is the attempt to develop a standardized set of mission-level measures to use in the evaluation of EC systems. A process needs to be developed to determine and establish a set of mission-level MOEs for the evaluation of EC systems. This is a topic broad enough to warrant a future research study.

Abbreviations and Acronyms

A

ACETEF	Air Combat Environment Test and Evaluation Facility
AF	Air Force
AFEWES	Air Force Electronic Warfare Evaluation Simulator
AFIA	Air Force Intelligence Agency
AFIC	Air Force Intelligence Command
AFM	Air Force Manual
AFOTEC	Air Force Operational Test and Evaluation Center
AFR	Air Force Regulation
AFSC	Air Force Systems Command
ASPJ	Airborne Self-Protection Jammer
ATIC	Avionics Test and Integration Complex

C

C^3	Command, Control, and Communications
C^3CM	Command, Control, and Communications Countermeasures
COEA	Cost and Operational Effectiveness Analysis
COI	Critical Operational Issue
CSAF	Chief of Staff, Air Force

D

Dem/Val	Demonstration and Validation
DIA	Defense Intelligence Agency
DMAP	Data Management and Analysis Plan
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DOT&E	Director, Operational Test and Evaluation
DT&E	Developmental Test and Evaluation

E

EC	Electronic Combat
ECM	Electronic Countermeasures
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMTE	Electromagnetic Test Environment
EOA	Early Operational Assessment
EW	Electronic Warfare
EWVA	Electronic Warfare Vulnerability Assessment

F

FOT&E	Follow-On Operational Test and Evaluation
FSD	Full-Scale Development

G

GAO	General Accounting Office
GPS	Global Positioning System
GTF	Ground Test Facility
GWEF	Guided Weapons Evaluation Facility

H

HITL	Hardware-in-the-Loop
HQ	Headquarters

I

IEEE	Institute of Electrical and Electronics Engineers
IG	Inspector General
IOC	Initial Operational Capability
IOT&E	Initial Operational Test and Evaluation
IR	Infrared
ISD	Information Systems Directive
ITEA	International Test and Evaluation Association

J

JCS	Joint Chiefs of Staff

L

LRIP	Low-Rate Initial Production

M

MAJCOM	Major Command
MITL	Man-in-the-Loop
MMW	Millimeter Wave
MNS	Mission Need Statement
MOE	Measure of Effectiveness
MOP	Measure of Performance
MS	Milestone
M/S	Modeling and Simulation

N

NBCC	Nuclear, Biological, and Chemical Contamination

O

OA	Operational Assessment
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OTA	Operational Test Agency
OT&E	Operational Test and Evaluation

P

PMD	Program Management Directive
PRIMES	Preflight Integration of Munitions and Electronic Systems
Pub	Publication

R

RCS	Radar Cross Section
REDCAP	Real-Time Electromagnetic Digitally Controlled Analyzer and Processor
RF	Radio Frequency
R&M	Reliability and Maintainability

S

SAF	Secretary of the Air Force
SIL	System Integration Laboratory
SIMVAL	Simulator Validation
SOA	Separate Operating Agency
SOF	Special Operations Forces
SON	Statement of Operational Need
SORD	System Operational Requirements Document
SPO	System Program Office
STAR	System Threat Assessment Report

T

TDD	Threat Description Document
T&E	Test and Evaluation
TEMP	Test and Evaluation Master Plan
TPO	Test Program Outline
TPWG	Test Planning Working Group
TSPI	Time-Space-Position Information

U

US	United States

V

VV&A	Verification, Validation, and Accreditation

Terms and Definitions

Attributed definitions are taken directly from sources cited.

Accreditation. The official determination that a model is acceptable for a specific purpose. ("AFOTEC Modeling and Simulation Accreditation Process," 4)

Acquisition. The procurement of real property by any means exclusive of lease agreements. The process consists of planning, designing, producing, and distributing a system or equipment. (AFR 55-43, *Management of Operational Test and Evaluation*, 49)

Acquisition Program. A directed effort funded either through procurement appropriations; through the security assistance program; or through the research, development, test, and evaluation appropriation, with the goal of providing a new or improved capability for a validated need. An acquisition program may include either the development or procurement of systems, subsystems, equipment, munitions, or modifications to them, as well as supporting equipment, systems, projects, and studies. Excluded from this definition . . . are the general-purpose, commercially available automatic data processing assets defined in Air Force 700-series regulations. (AFR 800-2, *Acquisition Program Management*, 1)

Affordability. A determination that the life-cycle cost of an acquisition program is in consonance with the long-range investment and force structure plans of the Department of Defense or individual DOD components. (DOD Instruction [DODI] 5000.2, *Defense Acquisition Management Policies and Procedures*, 15-2)

Analysis. The detailed examination and application of disciplined techniques (e.g., mathematics or statistics) to anything complex to understand its nature or determine its essential features. (AFR 55-43, 49)

Anechoic Chamber. A chamber in which free-space radiation of radio frequency (RF) emissions can take place that is free from echoes and reverberations. Used for testing an EC systems response and performance to RF stimulation.

Antenna Hat. A device placed over an antenna or sensor to facilitate the exchange of sensory information to the EC system or measurement instrumentation.

Assess. To collect, analyze, and report data regarding an aspect of the system in test not specifically identified as an operational requirement. (AFR 55-43, 49)

Atmospheric Attenuation. The process whereby the intensity of the frequency bands used for radar is weakened as they pass through the atmosphere. Attenuation is introduced by the air and water vapor, by rain and snow, by clouds and fog, and (at some frequencies) by electrons in the ionosphere.

Availability. A measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at an unknown (random) time. Availability is dependent upon reliability, maintainability, and logistics supportability. (AFR 55-43, 49)

Breadboard. An assembly of preliminary circuits or components used to prove the feasibility of a device, circuit, or principle without regard to the final configuration or packaging of the parts.

Capability. The ability to execute a specified course of action. (Joint Pub 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 60)

Combined Testing. Testing conducted by the development and operational testers when due to cost, schedule, or test item availability they must share test facilities and resources. (AFR 80-14, *Test and Evaluation*, 34)

Command, Control, and Communications (C^3). The process of, and the means for the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the commander's mission. C^3 functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures that are employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the commander's mission. (AFM 2-8, *Electronic Combat (EC) Operations*, 37)

Compatibility. Capability of two or more items or components of equipment or material to exist or function in the same system or environment without mutual interference. (Joint Pub 1-02, 82)

Computer Simulations. Digital models of EC systems, host platforms, the combat environment and/or threat systems that are executed together on a time and space domain in a simulation of combat conditions. (*Air Force Electronic Combat Development Test Process Guide* [hereafter cited as *AF EC Test Process Guide*], B-1)

Concept Exploration and Definition. The identification and exploration of alternative solutions or solution concepts to satisfy a validated need, usually through the use of contracts with competent industry and educational institutions. This phase requires the active involvement of all participating commands to identify the candidate solutions and their characteristics. One or more of the selected candidate solutions are then approved for entry into the demonstration and validation phase. [This phase was formerly called conceptual phase.] (AFM 11-1, *Air Force Glossary of Standardized Terms*, 4)

Cost and Operational Effectiveness Analysis (COEA). An analysis of the estimated costs and operational effectiveness of alternative materiel systems to meet a mission need and the associated program for acquiring each alternative. (DODI 5000.2, 15-3)

Cost Threshold. Expressions of value. They answer such questions as: How valuable is a given capability to the service? How much would the service be willing to give up in order to obtain that capability? At what point would it be preferable to drop the idea in favor of some other course of action? (DOD 5000.2-M, *Defense Acquisition Management Documentation and Reports*, 8-11)

Criteria. Plural of criterion.

Criterion. A rule or standard on which a judgment or decision may be based.

Critical Operational Issue (COI). A key operational effectiveness or operational suitability issue that must be examined in operational test and evaluation to determine the system's capability to perform its mission. A critical operational issue is normally phrased as a question to be answered in evaluating a system's operational effectiveness or operational suitability. (DODI 5000.2, 15-4)

Data Management and Analysis Plan (DMAP). A plan that details the procedures for processing test data into a form which can be presented as information to support measures of effectiveness (MOE) [and measures of performance (MOP)]. The DMAP should be a useful guide for data collection, reduction, processing, and analysis for each MOE [and MOP]. In addition, data presentation and disposal are also included. If done correctly, analysts and data technicians who are not familiar with the program should be able to follow the steps outlined in [the] DMAP. (*Operational Test and Evaluation Analysts Handbook*, 4-17)

Data Processing. The preparation of source media that contain data or basic elements of information, and the handling of such data according to precise rules of procedure to accomplish such operations as classifying, sorting, calculating, summarizing, and recording. (AFM 11-1, 25)

Data Reduction. The action or process of reducing data to usable form, usually by means of electronic computers and other electronic equipment. (AFM 11-1, 25)

Demonstration and Validation (dem/val). The period when selected candidate solutions are refined through extensive study and analyses: hardware development, if appropriate; tests; and evaluations. The objective is to validate one or more of the selected solutions and give a basis for deciding whether to proceed into full-scale development. (AFM 11-1, 4)

Development. The process of working out and extending the theoretical, practical, and useful applications of a basic design, idea, or scientific discovery. The design, building, modification, or improvement of the

prototype of a vehicle, engine, instrument, or the like, as determined by the basic idea or concept. (AFM 11-1, 27)

Developmental Test and Evaluation (DT&E). That testing and evaluation used to measure progress; verify accomplishment of development objectives; and determine if theories, techniques, and materiel are practicable and if systems or items under development are technically sound, reliable, safe, and satisfy specifications. (AFM 11-1, 27)

Digital Models. Computer models which consist entirely of software and require no unique hardware other than the particular main-frame, mini, or micro-computer for which they are targeted. (*AF EC Test Process Guide*, B-2)

Digital System Model (DSM). A computer model representing a system under development. The DSM is a software equivalent of the system. It aids engineering development. A DSM refers specifically to modular software developed to run under the common computer simulation architecture. (*AF EC Test Process Guide*, B-2)

DOD Components. The Office of the Secretary of Defense; the military departments; the chairman, Joint Chiefs of Staff and Joint Staff; the unified and specified commands; the defense agencies; and DOD field activities. (DODI 5000.2, 15-5)

Ducting. Confinement of electromagnetic waves to a restricted path in a given layer of air. A duct forms in the troposphere when a layer of cool air becomes trapped under a layer of warmer air, or when a layer of cool air becomes sandwiched between two layers of warmer air. The mode of propagation between the layers of air is similar to that of a waveguide. Low-loss transmission over great distances is possible via ducts, very distant radar echoes can be observed, and duct propagation constitutes a potential source of interference between cochannel radio users.

Early Operational Assessment (EOA). An operational assessment conducted before or in support of MS II. (AFR 55-43, 51)

EC Digital System Model. A computer model representing the EC system. This software equivalent of the EC system is used throughout the EC test process. EC digital system models are developed during the systems engineering process and will model the proposed EC system design. They are used in all levels of computer simulation to support system development, analysis, and testing. The SPO, along with help from the contractor, is responsible for developing the EC digital system model. It is also the duty of the SPO to maintain and update the EC model throughout the acquisition process.

Electromagnetic Spectrum. The range of frequencies of electromagnetic radiation from zero to infinity. It is divided into 26 alphabetically designated bands. (Joint Pub 1-02, 126)

Electronic Combat (EC). Action taken in support of military operations against the enemy's electromagnetic capabilities. Electronic combat includes electronic warfare (EW); elements of command, control, and communications countermeasures (C^3CM); and suppression of enemy air defenses (SEAD). (AFM 11-1, 30)

Electronic Combat (EC) System. Any equipment used to determine, exploit, reduce, or prevent hostile use of, or retain friendly use of, the electromagnetic spectrum. This includes associated support equipment, training devices, threat emitters and threat simulators. [AFR 55-24, *Electronic Warfare Integrated Reprogramming Policy* (U), 2 (Secret) Information extracted is unclassified.]

Electronic Countermeasures (ECM). The division of electronic warfare involving actions taken to prevent or reduce an enemy's effective use of the electromagnetic spectrum . . . includes electronic jamming and deception. (Joint Pub 1-02, 127)

Electronic Warfare Vulnerability Assessment (EWVA). The process (involving analysis, modeling, simulation, and test) which determines the degree of vulnerability of EC systems in their intended operational environment. EWVA is applied throughout the life of a system and includes evaluations of near-term (initial operational capability), mid-term (IOC + 5 [years]), and far-term (IOC + 10 [years]) threats, including system specific countermeasures to the fielded system. (*AF EC Test Process Guide*, B-3)

Engineering and Manufacturing Development. The period when the system and the principal items necessary for its support are designed, fabricated, tested, and evaluated. The intended output is, as a minimum, a preproduction system that closely approximates the final product; the documentation needed to enter the production phase; and the test results that show the product will meet the requirements. This phase includes the procurement of long-lead production items and limited production for operational test and evaluation. [This phase was formerly called full-scale development (FSD).] (AFM 11-1, 4)

Evaluate. To collect, analyze, and report against stated criteria, data about an aspect of the system in test specifically identified as an operational requirement. (AFR 55-43, 51)

Evaluation Criteria. Standards used to judge the achievement of required operational effectiveness or suitability characteristics or the resolution of technical or operational issues. (AFR 80-14, 34)

Exit Criteria. Program specific accomplishments that must be satisfactorily demonstrated before an effort or program can progress further in the current acquisition phase or transition to the next acquisition phase. Exit criteria may include such factors as critical test issues, the attainment of projected growth curves and baseline parameters, and the results of risk reduction efforts deemed critical to the decision to proceed further. Exit

criteria supplement minimum required accomplishments and are specific to each acquisition phase. (DODI 5000.2, 15-5)

Extrapolate. To project, extend, or expand known data into an area not known or experienced so as to gain some insight about the unknown area.

Feedback. A process by which a system or device is revised with the output from a machine, system, or process.

Follow-On Operational Test and Evaluation. That test and evaluation that is necessary during and after the production period to refine the estimates made during operational test and evaluation, to evaluate changes, and to reevaluate the system to ensure that it continues to meet operational needs and retains its effectiveness in a new environment or against a new threat. (DODI 5000.2, 15-6)

Human Factors. Those factors which contribute to the optimization of a system by integrating the human performance necessary to operate, maintain, support, and control the system in its intended operational environment. (AFR 80-14, 35)

Implementing Command. The command or agency designated by Headquarters, United States Air Force to manage an acquisition program. (AFR 800-2, 1)

Initial Operational Capability (IOC). The first attainment of the capability to employ effectively a weapon, item of equipment, or system of approved specific characteristics, and which is manned or operated by an adequately trained, equipped, and supported military unit or force. (Joint Pub 1-02, 181)

Initial Operational Test and Evaluation (IOT&E). All operational test and evaluation conducted on production or production representative articles, to support the decision to proceed beyond low-rate initial production. It is conducted to provide a valid estimate of expected system operational effectiveness and operational suitability. (DODI 5000.2, 15-7)

Installed Test Facility. Test resource which provides the capability to test EC systems while they are installed on, or integrated with, host platforms. (*AF EC Test Process Guide*, B-4)

Instrumentation. (1) The installation and use of electronic, gyroscopic, and other instruments for the purpose of detecting, measuring, recording, telemetering, processing, or analyzing different values or quantities as encountered in the flight of an aircraft, missile, or spacecraft. Instrumentation applies to both flight-borne and ground-based equipment. (2) The assemblage of such instruments in an aerospace vehicle, with each instrument designed and located so as to occupy minimum space, achieve minimum weight, yet function effectively. (AFM 11-1, 41)

Intelligence Report. A report provided by the appropriate intelligence agency/command to the milestone decision authority prior to each milestone review. For milestone 0, the report will confirm the validity of the

threat contained in the mission need statement. For milestones I-IV, the report will confirm the validation of the system threat assessment used in support of the program and will address any threat issues or unresolved threat concerns affecting the program.

Interoperability. The ability of systems, units or forces to provide services to and accept services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together. (Joint Pub 1-02, 190)

Life-Cycle Cost. The total cost to the government of acquisition and ownership of that system over its useful life. It includes the cost of development, acquisition, support, and, where applicable, disposal. (DODI 5000.2, 15-9)

Logistics Reliability. A measure of a system's ability to operate as planned under the defined operational and support concepts, using specified logistics resources (e.g., spares or manpower). Logistics reliability may be expressed as mean time between maintenance, mean time between removal, or mean time between demand. It recognizes the effect of all occurrences that place a demand on the logistics support system even when mission capability is unaffected. (AFM 11-1, 45)

Logistics Supportability. The degree to which planned logistics support (including test, measurement, and diagnostic equipment; spares and repair parts; technical data; support facilities; transportation requirements; training; manpower; and software support) allows meeting system availability and wartime usage requirements. (DODI 5000.2, 15-9)

Low-Rate Initial Production (LRIP). The production of a system in limited quantity to provide articles for operational test and evaluation, to establish an initial production base, and to permit an orderly increase in the production rate sufficient to lead to full-rate production upon successful completion of operational testing. (DODI 5000.2, 15-9)

Maintainability. A measure of the time or maintenance resource needed to keep an item operating or to restore it to operational (or serviceable, in the case of certain munitions) status. Maintainability may be expressed as the time to do maintenance (e.g., maintenance downtime per sortie), as a usage rate of manpower resources (e.g., maintenance—work hours per flying hour), as the total required manpower (e.g., maintenance personnel per operational unit), or as the time to restore a system to operational status (e.g., mean downtime). (AFM 11-1, 46)

Major Command (MAJCOM). A major subdivision of the Air Force that is assigned a major part of the Air Force mission. Major commands report directly to Headquarters United States Air Force (HQ USAF). (AFM 11-1, 47)

Many-Versus-Many. A test scenario in which a friendly force consisting of many aircraft and the EC system under test is pitted against many airborne or ground-based adversaries.

Mature System. A system is considered mature when its reliability and maintainability characteristics cease to improve significantly with continued use. Systems, subsystems, and components all mature at various rates for varying lengths of time. Unless otherwise specified, a system will be considered to have mature reliability and maintainability (R&M) characteristics two years after the initial operational capability (IOC) date. (AFR 55-43, 54)

Measure. Any standard of comparison, estimation, or judgment; criterion. (*The World Book Dictionary*, 1287)

Measurement Facilities. Test resources used for exploring and evaluating EC technologies. Data collected from these resources include antenna patterns, radar cross sections, and infrared and laser signatures. (*AF EC Test Process Guide*, B-5)

Measure of Effectiveness (MOE). A qualitative or quantitative measure of a system's performance at a mission level, or a characteristic that indicates the degree to which the system performs the task or meets the mission-level requirement under specified conditions.

Measure of Performance (MOP). A qualitative or quantitative measure of a system's performance at a system level, or a characteristic that indicates the degree to which the system performs the task or meets the system-level requirement under specified conditions.

Milestones (MS). Major decision points that separate the phases of an acquisition program. (DOD Directive 5000.1, *Defense Acquisition*, 2)

Minimum Acceptable Operational Requirement. The value for a particular parameter that is required to provide a system capability that will satisfy the validated mission need. Also known as the performance threshold. (DODI 5000.2, 15-11)

Mission Need Statement (MNS). A document prepared by the respective using command or HQ USAF that identifies an operational deficiency that cannot be satisfied through changes in tactics, strategies, doctrine, or training. A solution normally entails research and development, production, and procurement of a new capability or modification of an existing system. [Formerly called Statement of Operational Need (SON).] (AFM 11-1, 72)

Mission Reliability. A measure of the ability of a system to complete its planned mission or function. Mission reliability may be expressed as mission completion success probability, mean mission duration, or as mean time between critical failure, as appropriate. (AFM 11-1, 50)

Model. A representation of an actual or conceptual system that involves mathematics, logical expressions, or computer simulations that can be used to predict how the system might perform or survive under various conditions or in a range of hostile environments. (DODI 5000.2, 15-11)

Multispectral Threat Environment. An environment consisting of threat emissions from several spectra, especially from parts of the visible, infrared, and microwave spectra.

One-Versus-Few Engagement. A scenario in which a single EC system under test is pitted against several adversaries.

One-Versus-One Engagement. A scenario in which a single EC system under test is pitted against a single adversary.

Operational Assessment (OA). An evaluation of operational effectiveness and operational suitability made by an independent operational test activity, with user support as required, on other than production systems. The focus of an operational assessment is on significant trends noted in development efforts, programmatic voids, areas of risk, adequacy of requirements, and the ability of the program to support adequate operational testing. Operational assessments may be made at any time using technology demonstrators, prototypes, mockups, engineering development models, or simulations but will not substitute for the independent operational test and evaluation necessary to support full production decisions (DODI 5000.2, 15-13)

Operational Effectiveness. The overall degree of mission accomplishment of a system when used by representative personnel in the environment planned or expected (e.g., natural, electronic, threat, etc.) for operational employment of the system considering organization, doctrine, tactics, survivability, vulnerability, and threat (including countermeasures, initial nuclear weapons effects, nuclear, biological, and chemical contamination (NBCC) threats). (DODI 5000.2, 15-13)

Operational Reliability. The probability that an operationally ready system will react as required to accomplish its intended mission or function as planned, excluding the effects of enemy action; may be specified as an estimated or an achieved reliability. (AFR 55-43, 55)

Operational Requirement. An established need justifying the timely allocation of resources to achieve a capability to accomplish approved military objectives, missions, or tasks. (Joint Pub 1-02, 264)

Operational Requirements Document (ORD). A document prepared by the respective using command that describes pertinent quantitative and qualitative performance, operation, and support parameters, characteristics, and requirements for a specific candidate weapon system. The [ORD] documents how a system will be operated, deployed, employed, and supported and provides initial guidance for the implementing, supporting, and participating commands and agencies. [Formerly called System Operational Requirements Document (SORD).] (AFM 11-1, 74)

Operational Suitability. The degree to which a system can be placed satisfactorily in field use with consideration given to availability, compatibility, transportability, interoperability, reliability, wartime usage rates, main-

tainability, safety, human factors, manpower supportability, logistics supportability, natural environmental effects and impacts, documentation, and training requirements. (DODI 5000.2, 15-13)

Operational Test Agency (OTA). The command or agency designated by the program management directive (PMD) or other appropriate program directive as responsible for managing the independent OT&E of a system. (AFR 55-43, 55)

Operational Test and Evaluation (OT&E). *Testing and evaluation* (divided into initial operational test and evaluation and follow-on operational test and evaluation, and generally associated with the first major production decision) conducted in as realistic an operational environment as possible to estimate the prospective system's military utility, operational effectiveness, and operational suitability. In addition, operational test and evaluation provides information on organization, personnel requirements, doctrine, and tactics. Also, it may provide data to support or verify material in operating instructions, publications, and handbooks. (AFM 11-1, 54)

Operational Test and Evaluation (OT&E) Plan. The document prepared by the OT&E agency that details the background, scope, and procedures for conducting OT&E. (AFR 55-43, 55)

Participating Command. A command or agency designated by Headquarters United States Air Force to support and advise the program manager (PM). The supporting command is also a participating command. (AFR 800-2, 2)

Performance. Those operational and support characteristics of the system that allow it to effectively and efficiently perform its assigned mission over time. The support characteristics of the system include both supportability aspects of the design and the support elements necessary for system operation. (DODI 5000.2, 15-13)

Performance Threshold. *See* minimum acceptable operational requirement.

Preproduction-Representative. An article in final form employing standard parts representative of articles to be produced on a production line with production tooling.

Production and Deployment. The period from production approval until the last system is delivered and accepted. The objective is to efficiently produce and deliver effective and supportable systems to the operating units. This includes the production of all principal and support equipment. The deployment phase encompasses the process of uniting facilities, hardware and software, personnel, and procedural publications; and delivering an acceptable integrated system to the using and supporting commands. This overlaps the production phase. [This phase was formerly

divided into two separate phases called production phase and deployment phase.] (AFM 11-1, 4)

Production System. A system which is in final form, employs standard parts, and is representative of final equipment.

Program Management Directive (PMD). The official Air Force document used to direct acquisition or modification responsibilities to appropriate Air Force MAJCOMs for the development, acquisition, or modification of a specific weapon system, subsystem, or piece of equipment. It is used throughout the acquisition cycle to terminate, initiate, or direct research; development; production; or Class III, IV, or V modifications for which sufficient resources have been identified. States program unique requirements, goals, and objectives, especially those to be met at each acquisition milestone or program review. (AFM 11-1, 59)

Prototype. A model suitable for evaluation of design, performance, and production potential. (Joint Pub 1-02, 290)

Realistic Test Environment. The conditions under which the system is expected to be operated and maintained, including the natural weather and climatic conditions, terrain effects, battlefield disturbances, and enemy threat conditions. (AFR 55-43, 57)

Reliability. The ability of a system and its parts to perform its mission without failure, degradation, or demand on the support system.

Research Testing. Operations performed as a part of research experiments and investigations to measure, verify, or assess phenomena, hypotheses, and results of experimentation; and to gain new knowledge. (AFM 11-1, 66)

Simulation. A method for implementing a model. It is the process of conducting experiments with a model for the purpose of understanding the behavior of the system modeled under selected conditions or of evaluating various strategies for the operation of the system within the limits imposed by developmental or operational criteria. Simulation may include the use of analog or digital devices, laboratory models, or "testbed" sites. Simulations are usually programmed for solution on a computer; however, in the broadest sense, military exercises and wargames are also simulations. (DODI 5000.2, 15-15)

Simulator. A generic term used to describe a family of equipment used to represent threat weapon systems in developmental testing, operational testing, and training. A threat simulator has one or more characteristics which, when detected by human senses or man-made sensors, provide the appearance of an actual threat weapon system with a prescribed degree of fidelity. (DODI 5000.2, 15-15)

Supportability. The degree to which system design characteristics and planned logistics resources, including manpower, meet system peacetime readiness and wartime utilization requirements. (DODI 5000.2, 15-16)

Supporting Command. The command assigned responsibility for providing logistics support; it assumes program management responsibility from the implementing command. (AFR 800-2, 2)

System Effectiveness. A measure of the extent to which a system may be expected to achieve a set of specific mission requirements expressed as a function of availability, dependability, and capability. (AFM 11-1, 74)

System Program Office (SPO). The organization comprised of technical, administrative, and business management personnel assigned full time to a system program director. The office may be augmented with additional personnel from participating organizations. (AFM 11-1, 74)

System Threat Assessment. Describes the threat to be countered and the projected threat environment. The threat information should reference DIA or Service Technical Intelligence Center approved documents. (DODI 5000.2, 15-17)

System Threat Assessment Report (STAR). An intelligence document that serves as the single authoritative reference for threat data regarding a weapon system acquisition program. It describes the lethal and non-lethal threats against the proposed US system and the threat environment in which the system will operate. (AFM 11-1, 75)

Test and Evaluation (T&E). Actions taken to ensure that a system achieves performance requirements. The term *test* denotes any project or program designed to obtain, verify, and provide data to evaluate research and development other than laboratory experiments; progress in accomplishing development objectives; performance and operational capability of systems, subsystems, and components; and equipment items. The term *evaluation* denotes the review and analysis of quantitative data produced during current or previous testing and data obtained from tests conducted by other government agencies and contractors, from operation and commercial experience, or combinations thereof. (AFR 55-43, 59)

Test and Evaluation Master Plan (TEMP). The basic planning document for all T&E related to a particular system acquisition, and is used in planning, reviewing and approving T&E. It is required for all major defense acquisition programs, all OSD oversight programs, all HQ USAF programs directed by a PMD, and may be required for an ISD directed information system program. The TEMP integrates critical issues, test objectives, evaluation criteria, system characteristics, responsibilities, resources, and schedules for T&E. (AFR 55-43, 59)

Test Article. The EC system or system components to be tested.

Testbed. A system representation consisting partially of actual hardware and/or software and partially of computer models or prototype hardware and/or software. (DODI 5000.2, 15-17)

Test Conditions. The environment (e.g., location, weather), scenario, and operating procedures and configurations for the SUT [system under test] and adversaries in the test scenario. (*AF EC Test Process Guide*, B-9)

Test Design. The combination(s) of test trial, test environment, and test condition parameters used to construct a test sequence. (*AF EC Test Process Guide*, B-9)

Test Director. The person assigned to conduct a test according to a test plan, who exercises overall responsibility for achieving plan objectives. (AFR 55-43, 59)

Test Environment. The test location, atmospheric conditions, multispectral emissions from the threat emitters or test items, instrumentation and collection devices, and so forth, in which the test is conducted.

Test Event. An activity during conduct of a test trial that requires a response by the system and/or personnel under test. (*AF EC Test Process Guide*, B-9)

Test Manager. The person designated as the focal point for advance planning, OT&E planning, executing the test, and reporting on an OT&E program. (AFR 55-43, 59)

Test Objective. The specific performance or technical parameters to be measured during the test to evaluate system performance, system operational effectiveness, or system suitability. (*AF EC Test Process Guide*, B-9)

Test Planning Working Group (TPWG). [A team] assigned by the program manager to provide a forum for test-related subjects; assists in establishing test objectives and evaluation baselines; defines organization, responsibilities, and relationships; estimates costs and schedules; and identifies needed test resources. Normally, includes system program office (SPO) representatives, AFSC test agencies, contractors, AFOTEC, and using and supporting major commands. (AFR 55-43, 59)

Test Program Outline (TPO). The basic resource management document used throughout the OT&E planning process. It identifies resources required to support testing and is the basis for budget submissions, manpower plans, and procurement leadtime. (AFR 55-43, 59)

Test Resources. Assets that support the test and evaluation of the EC system. They include the test facilities, models, threat simulators, friendly support assets, instrumentation systems, range-tracking systems, mission control centers, test facilities, environment generators, and so forth.

Test Scenario. A situation, representative of what the system under test may encounter in real life, that is used to enact a set of events between it and adversaries included in the situation (e.g., threat simulator locations and flight profiles). (*AF EC Test Process Guide*, B-9)

Test Sequence. The ordering from first to last of the test trials in the test design. (*AF EC Test Process Guide*, B-9)

Test Trial. A single case of a test design that measures the values of the performance or technical parameters in a specific test facility under the same test conditions. (*AF EC Test Process Guide*, B-9)

Threat Replica. A device which has all the externally observable characteristics of and is a close reproduction of the actual threat system.

Threshold. Minimum acceptable value for a performance parameter necessary to provide an operational capability that will satisfy the mission need. (AFR 57-1, *Air Force Mission Needs and Operational Requirements Process*, 133)

Time-Space-Position Information (TSPI). A coordinate reference system that provides a method to locate an object in space and time. It can consist of several types of coordinate reference systems such as global positioning system (GPS), radar, laser range tracking cinesextant, cinetheodolite, high-speed camera, and so forth. A TSPI system is used to track aircraft or missiles; to provide overall mission control; to determine the three-dimensional position of the system under test; to provide positive identification of aircraft on the range for evaluating mission or engagement events; and to determine aircraft or missile velocity, acceleration, and attitude for inputs to scoring simulations.

Uninstalled Test Facility. A test resource which provides the capability to test EC systems before they are installed or mounted in their host platform for the purpose of evaluating the effectiveness of the EC systems hardware and techniques.

Using Command. The major command responsible for system employment. (*AF EC Test Process Guide*, B-9)

Validation. The process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model. Validation is also a process of building confidence in the model to a satisfactory level so that a valid inference about the actual system can be made with the model. ("AFOTEC Modeling and Simulation Accreditation Process," 3)

Verification. The process of determining that a model implementation accurately represents the developer's conceptual description and specification. It is a process that is used to ensure a model's internal data, structure and logic correctly behaves in a manner that represents the system being modeled. ("AFOTEC Modeling and Simulation Accreditation Process," 2)

Waveguide. A device (such as a duct, coaxial cable or glass fiber) designed to confine and direct the propagation of electromagnetic waves.

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Operational Test and Evaluation of Electronic Combat Systems

Wright